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Physical Properties, Empirical Relations and Thermal Gradients of Olive/Corn Oils Mixtures and Olive/Acetone Solutions

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استكمالاً لمتطلبات الحصول على درجة الماجستير في الفيزياء.

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Dedication

This thesis is dedicated to my father and my mother. It is also dedicated to my professor Dr. Hussien Al-Omari.

Mohammad Al-Dmour

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Mohammad Al-Dmour

List of Contents

List of Tables

List of Figures

List of Abbreviations

Association of American Feed Control Officials	*AAFCO*	A consultancy company specialising in bioenergy, biofuels and bio-based products	*NNFCC*
Low Density Lipoprotein	*LDL*	Coronary Heart Disease	*CHD*
Ribonucleic Acid	*RNA*	Deoxyribonucleic Acid	*DNA*
Refractive index	*N*	Trichloroacetic Acid	*TCA*
Speed of light in vacuum	*C*	The angle of incidence of a ray crossing the interface between two media	Θ
Cauchy's Equation	*CE*	speed of light in the substance	*V*
Clausius Mossotti Relation	*CMR*	Lorentz Lorenz Equation	*LLE*
Newton Equation	*NE*	Arago Biot Equation	*ABE*
Gladstone Dale Relation	*GDR*	Maxwell's Formula	*MF*
Eyring John equation	*EJE*	Heller Relation	*HR*
Oster Relation	*OR*	Eykman Relation	*ER*
The density	*P*	Wiener relation	*WR*
The D line refractive index	n_D	The specific refraction	R_D
Visible Light Spectra	*VLS*	The fitting constants of the polynomial equation	*A,B,C*
The optical permittivity	*E*	The wave length	Λ
The concentration	*C*	The absolute temperature	*T*
specific refractive index increment	*dn/dc*	Ultra Violet	*UV*
Association of Analytical Communities	*AOAC*	The temperature gradient of refractive index	*dn/dT*
The dynamic or absolute viscosity	*H*	The temperature gradient of density	$d\rho/dT$
The shear stress	*T*	The kinematic viscosity	*N*
The temperature gradient of dynamic viscosity	$d\eta/dT$	The rate of deformation	Γ
the activation energy	E_a	Frenkel Eyring equation	*FEE*
Coefficient of thermal expansion	γ_V	The ideal gas constant	*R*
The volume	*V*	The volume fraction of pure component	Φ
Andrade Equation	*AE*	The pressure	*P*
Prod'homme Relation	*PR*	Vogel Equation	*VE*

Abstract

Physical Properties, Empirical Relations and Thermal Gradients of Olive/Corn Oils Mixtures and Olive/Acetone Solutions

Mohammad Al-Dmour

Mu'tah University, 2014

Densities, refractive indices, viscosities and thermal expansions have been experimentally determined at the temperature range 19 to 51°C for olive/corn oil mixtures (with different concentrations 0%, 10% - 90%, 100%) and olive/acetone solutions (with different concentrations 5%, 10% - 35%, 40%). The densities for all samples were pycnometrically measured. The refractive indices were measured at the required temperatures with the thermo stated highly précised Abbes refractometer at the visible D spectral line (Na, λ = 589nm). A comparative study has been reported for all samples between the mixing rules equations of Lorentz Lorenz equation, Arago Biot equation, Newton equation, Gladstone Dale relation and Eyring John equation using refractive index and density measurements. The specific refraction was calculated from the theoretical models of Lorentz Lorenz equation, Gladstone Dale relation, Eykman relation, Newton equation, Oster relation and Arago Biot equation. In this study has been verified that the specific refraction is independent on temperature for all theoretical modeling equations. The dynamic viscosities were measured at the required temperatures using falling ball viscometer for all concentrations of olive/corn oil mixtures and olive/acetone solutions. The activation energies for all samples were calculated using Frenkel Eyring Arrhenius type equation. A comparative study has been reported for all samples between the theoretical models of Andrade and Vogel, which are describe the effect of temperature on the dynamic viscosity. This study reveals that the empirical relation which gives the best prediction for the temperature dependence of dynamic viscosity is described by Vogel equation. The thermal expansion coefficients have been defined experimentally by volumetric method and optically by Prod'homme relation.

الملخص

الخصائص الفيزيائية و العلاقات المعيارية الوصفية و الانحدارات الحرارية لمزائج زيت الزيتون و زيت الذرة و لمحاليل زيت الزيتون و الاسيتون

محمد كريم الضمور

جامعة مؤتة، 2014

الكثافه و معامل الانكسار و اللزوجة و معامل التمدد الحراري تم قياسها عند درجات الحرارة بين 19 و 51 سيلسيوس لمزيج زيت الزيتون و زيت الذرة (عند التراكيز 0%، 10% – 90%، 100%) و محلول زيت الزيتون و الاسيتون (عند التراكيز 5%، 10% – 35%، 40%). كثافة جميع العينات تم قياسها بالطريقة الحجمية. معاملات الانكسار تم قياسها عند درجات الحرارة بواسطة رفراكتوميتر ابي عالي الدقة عند خط الطول الموجي للضوء المرئي للصوديوم. تم عرض دراسة مقارنة خضعت لها جميع العينات بين تطبيق معادلات المزج لكل من لورنتز لورنز وارقو بيوت ونيوتن قلادستون ديل ايرنق جون مستخدمين القيم المقاسة لكل من معامل الانكسار والكثافة. تم أيضا حساب قيم الانكسار النوعي مستخدمين النماذج النظرية لمعادلات كل من لورنتز لورنز وقلادستون ديل وايكمان ونيوتن واوستر وارقو بيوت. في هذه الدراسة تم التحقق من ان الانكسار النوعي ثابت مع الحرارة لجميع معادلات النماذج النظرية. اللزوجة الديناميكية تم قياسها عند درجات الحرارة لجميع تراكيز مزيج زيت الزيتون وزيت الذرة محلول زيت الزيتون والاسيتون باستخدام جهاز الكرات الساقطة. قيم طاقة الحفز لجميع العينات تم حسابها من خلال معادلة فرينكل ايرنج. تم عرض دراسة مقارنة خضعت لها جميع العينات بين تطبيق النموذجين النظريين لكل من اندريد وفوجيل والذين يصفان التأثير الحراري على اللزوجة الديناميكية. اثبتت هذه الدراسة ان العلاقة المعيارية التي تعطي ادق وصف لتأثير الحرارة على اللزوجة الديناميكية هي معادلة فوجيل. تم قياس معاملات التمدد الحراري تجريبيا من خلال الطريقة الحجمية وبصريا من خلال علاقة برودهوم.

CHAPTER ONE
INTRODUCTION

1.1. Vegetable Oils: General Information, Industrial, Food and Health Importance.

A vegetable oil is a triglyceride extracted from a plant. Such oils have been part of human culture for millennia. The term "vegetable oil" can be narrowly defined as referring only to plant oils that are liquid at room temperature, or broadly defined without regard to a substance's state of matter at a given temperature. For this reason, vegetable oils that are solid at room temperature are sometimes called vegetable fats. Vegetable oils are composed of triglycerides, as contrasted with waxes which lack glycerin in their structure. Although many plant parts may yield oil, in commercial practice, oil is extracted primarily from seeds (Farines *et al*., 1988).

Oils extracted from plants have been used since ancient times and in many cultures (Stamatas *et al*., 2008). As an example, in a 4,000-year-old kitchen unearthed in Indiana's Charlestown State Park, archaeologist Bob McCullough of Indiana University-Purdue University Fort Wayne found evidence that natives used large slabs of rock to crush hickory nuts, then boiled them in water to extract the oil. Many vegetable oils are consumed directly, or indirectly as ingredients in food – a role that they share with some animal fats, including butter and ghee. The oils serve a number of purposes in this role:

1. Shortening – to give pastry a crumbly texture.
2. Texture – oils can serve to make other ingredients stick together less.
3. Flavor – while less-flavorful oils command premium prices, some oils, such as olive, sesame, or almond oil, may be chosen specifically for the flavor they impart.
4. Flavor base – oils can also "carry" flavors of other ingredients, since many flavors are present in chemicals that are soluble in oil.

Secondly, oils can be heated and used to cook other foods. Oils suitable for this objective must have a high flash point. Such oils include the major cooking oils – soybean, canola, safflower, peanut, cottonseed, etc. Tropical oils, such as coconut, palm, and rice bran oils, are particularly valued in Asian cultures for high temperature cooking, because of their unusually high flash point (Suhane *et al*., 2012).

Unsaturated vegetable oils can be transformed through partial or complete "hydrogenation" into oils of higher melting point.

The hydrogenation process involves "sparging" the oil at high temperature and pressure with hydrogen in the presence of a catalyst, typically a powdered nickel compound. As each carbon–carbon double-bond is chemically reduced to a single bond, two hydrogen atoms each form single bonds with the two carbon atoms. The elimination of double

bonds by adding hydrogen atoms is called saturation; as the degree of saturation increases, the oil progresses toward being fully hydrogenated. Oil may be hydrogenated to increase resistance to rancidity (oxidation) or to change its physical characteristics (Robards *et al.*, 1988). As the degree of saturation increases, the oil's viscosity and melting point increase. The use of hydrogenated oils in foods has never been completely satisfactory. Because the center arm of the triglyceride is shielded somewhat by the end fatty acids, most of the hydrogenation occurs on the end fatty acids, thus making the resulting fat more brittle. A margarine made from naturally more saturated oils will be more plastic (more "spreadable") than margarine made from hydrogenated soy oil. While full hydrogenation produces largely saturated fatty acids, partial hydrogenation results in the transformation of unsaturated CIS fatty acids to Tran's fatty acids in the oil mixture due to the heat used in hydrogenation. Partially hydrogenated oils and their Trans fats have been linked to an increased risk of mortality from coronary heart disease (CHD), among other increased health risks. In the US, the Standard of Identity for a product labeled as "vegetable oil margarine" specifies only canola, safflower, sunflower, corn, soybean, or peanut oil may be used. Products not labeled "vegetable oil margarine" do not have that restriction (Babaee *et al*., 2007; Sarma *et al*., 2011). There are many scientific studies on the physical and chemical properties of hydrogenated and non hydrogenated of edible oils (Rudan Tasic and Klofutar, 1997; Toscano and Maldini, 2007; Blin *et al.*, 2013). Talkit et al., study the physicochemical properties of pure and binary mixtures of vegetable oils (2012).

Vegetable oils are used as an ingredient or component in many manufactured products. Many vegetable oils are used to make soaps, skin products, candles, perfumes and other personal care and cosmetic products. Some oils are particularly suitable as drying oils, and are used in making paints and other wood treatment products (Carrick, 1950). Dammar oil (a mixture of linseed oil and dammar resin), for example, is used almost exclusively in treating the hulls of wooden boats. Vegetable oils are increasingly being used in the electrical industry as insulators as vegetable oils are not toxic to the environment (Hosier *et al.*, 2009), biodegradable if spilled and have high flash and fire points (Bashi *et al.*, 2006). However, vegetable oils are less stable chemically, so they are generally used in systems where they are not exposed to oxygen, and they are more expensive than crude oil distillate (Erhan *et al.*, 2006). Synthetic tetra esters, which are similar to vegetable oils but with four fatty acid chains compared to the normal three found in a natural ester, are manufactured by Fischer esterification (Pavia *et al*., 2006). Tetra esters generally have high stability to oxidation and have found use as engine lubricants. Vegetable oil is being used to produce biodegradable hydraulic fluid

and lubricant (Gawrilow, 2004). One limiting factor in industrial uses of vegetable oils is that all such oils eventually chemically decompose, turning rancid. Oils that are more stable, such as ben oil or mineral oil, are preferred for some industrial uses (Abdulkarim *et al*., 2007). Vegetable-based oils, like castor oil, have been used as medicine and as lubricants for a long time. Castor oil has numerous industrial uses, primarily due to the presence of hydroxyl groups on the fatty acid chains. Castor oil, and other vegetable oils which have been chemically modified to contain hydroxyl groups, are becoming increasingly important in the production of polyurethane plastic for many applications (Narine and Kong, 2005). These modified vegetable oils are known as natural oil polyols (Sharma and Kundu, 2008).

Vegetable oil is used in production of some pet foods. The Association of American Feed Control Officials "AAFCO" defines vegetable oil, in this context, as the product of vegetable origin obtained by extracting the oil from seeds or fruits which are processed for edible purposes. In some poorer grade pet foods, the oil is listed only as "vegetable oil", without specifying the particular oil. Vegetable oils are also used to make biodiesel, which can be used like conventional diesel (Elsolh, 2011). Some vegetable oil blends are used in unmodified vehicles but straight vegetable oil, also known as pure plant oil, needs specially prepared vehicles which have a method of heating the oil to reduce its viscosity (Martin and Prithviraj, 2011). The vegetable oil economy is growing and the availability of biodiesel around the world is increasing. The consultancy company specializing in bioenergy, biofuels and bio-based products "NNFCC" estimate that the total net greenhouse gas savings when using vegetable oils in place of fossil fuel-based alternatives for fuel production range from 18 to 100%. The physical and chemical characteristics of vegetable oils as a biofuel have been studied in many scientific works (Toscano and Maldini, 2007; Blin *et al.*, 2013).

The production process of vegetable oil involves the removal of oil from plant components, typically seeds. This can be done via mechanical extraction (crushing or pressing) using an oil mill or chemical extraction using a solvent. The extracted oil can then be purified and, if required, refined or chemically altered. The method of mechanical extraction is typically used to produce the more traditional oils (e.g., olive, coconut etc.), and it is preferred by most "health-food" customers in the world. There are several different types of mechanical extraction (Straccia *et al.*, 2012). Expeller-pressing extraction is common, though the screw press, ram press, and Ghani (powered mortar and pestle) are also used. Oil seed presses are commonly used in developing countries, among people for whom other extraction methods would be prohibitively expensive; the Ghani is primarily used in India. The amount of oil extracted using these methods vary widely. The processing vegetable oil in commercial applications is

commonly done by chemical extraction, using solvent extracts, which produces higher yields and is quicker and less expensive (Eddy, 1922). The most common solvent is petroleum-derived hexane (Sivarao *et al*., 2012). This technique is used for most of the "newer" industrial oils such as soybean and corn oils. Supercritical carbon dioxide can be used as a non-toxic alternative to other solvents (Micic *et al.*, 2011).

1.2. Olive Oil, Corn Oil and Acetone: General Information, Industrial, Food and Health Importance.

Olive oil is a fat obtained from the olive (the fruit of Olea europaea; family Oleaceae), a traditional tree crop of the Mediterranean Basin. The oil is produced by pressing whole olives (Medina *et al.*, 2013). It is commonly used in cooking, cosmetics, pharmaceuticals, and soaps and as a fuel for traditional oil lamps. Olive oil is used throughout the world, especially in the Mediterranean countries and, in particular, in Spain, Portugal, Italy, and Greece, which has the highest consumption per person (Turkekul *et al.*, 2010; Quiles *et al.*, 2006). Jordan and the other Middle East countries has been cultivating olive trees and producing olive oil for over 6,000 years. Jordan ranks 8th worldwide in the production of olives and olive oil, producing an annual average of 190,000 tons of olive oil from 15 million trees. Olive orchards produce the most important fruit in Jordan and are concentrated in two regions: the western mountain range that crosses the kingdom north-south produces 70% of the country’s output, while farms in the eastern and southern part of country produce 30%. The former is rain-fed, while the latter is irrigated. The predominant olive varieties are Nabali and Rasie, both indigenous, and Souri (Al-Ismail *et al.*, 2011).

Olive oil is composed mainly of the mixed triglyceride esters of oleic acid, palmitic acid and of other fatty acids, along with traces of squalene (up to 0.7%) and sterols (about 0.2% phytosterol and tocosterols) (Andrikopoulos *et al.*, 2001). The composition varies by cultivar, region, altitude, time of harvest, and extraction process (Ghanbari *et al.*, 2012). There are several scientific researches on the physical and chemical properties of olive oil (Rudan Tasic and Klofutar, 1999; Di Mattia *et al.*, 2013)

Preliminary clinical studies provide evidence that consumption of olive oil may lower risk of heart disease risk factors such as lower blood cholesterol levels and reduced LDL cholesterol oxidation, and that it may also possibly influence inflammatory, thrombotic, hypertensive and vasodilatory mechanisms (Ruiz-Canela and Martinez-Gonzalez, 2011; Covas, 2007; Quiles *et al.*, 2006). Although epidemiological studies indicate that a higher proportion of monounsaturated fats in the diet may be linked with a reduction in the risk of coronary heart disease, a cause and

effect relationship has not yet been established with sufficient scientific evidence. Other possible effects of olive oil may be a property to balance omega-6 fats and omega-3 fats and to affect blood sugar levels and blood pressure, but these effects were dismissed in reviews by the Scientific Committee of the European Food Safety Authority (Simopoulos, 2006). Olive oil contains the monounsaturated fatty acid oleic acid, vitamin E and oleuropein, a chemical that may affect the oxidation of LDL particles (Castaner *et al.*, 2012). Preliminary research indicates that olive oil could possibly be a chemopreventive agent for peptic ulcer or gastric cancer, but confirmation requires further in vivo study (Medina *et al.*, 2013). Extra-virgin olive oil has been hypothesized to have chemopreventive effects on breast cancer, unlike high corn oil diets that stimulate it (Solanas *et al.*, 2010). Pilot studies showed that olive oil may reduce oxidative damage to DNA and RNA, revealing a possible anti-carcinogenic factor (Fito *et al.*, 2007). Consumption of olive oil may prevent the onset of Alzheimer's disease, possibly through a mechanism related to oleocanthal inhibiting fibrillization of tau protein (Farooqui, 2012). Olive oil has been investigated as a new photonic liquid crystal for optical communication systems (Al-Dergazly and Fadhel, 2007).

Corn oil (maize oil) is oil extracted from the germ of corn (maize). Its main use is in cooking, where its high smoke point makes refined corn oil valuable frying oil. It is also a key ingredient in some margarine. Corn oil is generally less expensive than most other types of vegetable oils. One bushel of corn contains 1.55 pounds of corn oil (2.8% by weight). Corn agronomists have developed high-oil varieties; however, these varieties tend to show lower field yields, so they are not universally accepted by growers. Corn oil is also a feedstock used for biodiesel (Mata *et al.*, 2012). Other industrial uses for corn oil include soap, salve, paint, rust proofing for metal surfaces, inks, textiles, nitroglycerin, and insecticides. It is sometimes used as a carrier for drug molecules in pharmaceutical preparations (Kim *et al.*, 2001). There are several scientific researches on the physical and chemical properties of corn oil (Toscano and Maldini, 2007; Rudan Tasic and Klofutar, 1999; Blin *et al.*, 2013).

Almost all corn oil is expeller pressed, then solvent extracted using hexane or 2-methylpentane (isohexane). The solvent is evaporated from the corn oil, recovered, and re-used. After extraction, the corn oil is then refined by degumming and/or alkali treatment, both of which remove phosphatides. Alkali treatment also neutralizes free fatty acids and removes color (bleaching). Final steps in refining include winterization (the removal of waxes), and deodorization by steam distillation of the oil at 232–260 °C (450–500 °F) under a high vacuum. Some specialty oil producers manufacture unrefined, 100% expeller pressed corn oil. This is a more

expensive product since it has a much lower yield than the combination expeller and solvent process, as well as smaller market share.

Some medical research suggests that excessive levels of omega-6 fatty acids, relative to omega-3 fatty acids, may increase the probability of a number of diseases and depression. Modern Western diets typically have ratios of omega-6 to omega-3 in excess of 10 to 1, some as high as 30 to 1, partly due to corn oil which has an omega-6 to omega-3 ratio of 49:1 (Shapiro, 1999). The optimal ratio is thought to be 4 to 1 or lower. A high intake of omega-6 fatty acids may increase the likelihood that postmenopausal women will develop breast cancer. Similar effects were observed on prostate cancer. Other analysis suggested an inverse association between total polyunsaturated fatty acids and breast cancer risk (Solanas *et al.*, 2010).

Acetone (systematically named propanone) is the organic compound with the formula $(CH_3)_2CO$. It is a colorless, mobile, flammable liquid, and is the simplest ketone. Acetone is miscible with water and serves as an important solvent in its own right, typically for cleaning purposes in the laboratory. About 6.7 million tones were produced worldwide in 2010, mainly for use as a solvent and production of methyl methacrylate and bisphenol A. It is a common building block in organic chemistry. Familiar household uses of acetone are as the active ingredient in nail polish remover and as paint thinner. Acetone is produced and disposed of in the human body through normal metabolic processes. It is normally present in blood and urine (Matteo and Widmark, 1919). People with diabetes produce it in larger amounts. Reproductive toxicity tests show that it has low potential to cause reproductive problems. Pregnant women, nursing mothers and children have higher levels of acetone. Ketogenic diets that increase acetone in the body are used to reduce epileptic attacks in infants and children who suffer from recalcitrant refractory epilepsy (Owen *et al.*, 1982).

Acetone is a good solvent for many plastics and some synthetic fibers (Pramod and Pandey, 2014). It is used for thinning polyester resin, cleaning tools used with it, and dissolving two-part epoxies and superglue before they harden. It is used as one of the volatile components of some paints and varnishes (Kijevcanin *et al.*, 2012). As a heavy duty degreaser, it is useful in the preparation of metal prior to painting. It is also useful for high reliability soldering applications to remove rosin flux after soldering is complete; this helps to prevent the Rusty bolt effect. Acetone is used as a solvent by the pharmaceutical industry and as a denaturant in denatured alcohol. Acetone is also present as an excipient in some pharmaceutical drugs (Yadav and Patil, 2013). Although itself flammable, acetone is used extensively as a solvent for the safe transporting and storing of acetylene, which cannot be safely pressurized as a pure compound.

Vessels containing a porous material are first filled with acetone followed by acetylene, which dissolves into the acetone. One liter of acetone can dissolve around 250 liters of acetylene.

Acetone is used in a variety of general medical and cosmetic applications and is also listed as a component in food additives and food packaging (Kijevcanin *et al.*, 2012; Choi *et al.*, 2011). Dermatologists use acetone with alcohol for acne treatments to peel dry skin. Acetone is commonly used in chemical peeling. Common agents used today for chemical peels are salicylic acid, glycolic acid, 30% salicylic acid in ethanol, and trichloroacetic acid (TCA). Prior to chemexfoliation, the skin is cleaned and excess fat removed in a process called defatting (Maki and McCormack, 1987). Acetone, Septisol, or a combination of these agents is commonly used in this process. In 1999, Zwijnenberg reported the sudy of using acetone as a solvent in vegetable oils (Zwijnenberg *et al.*, 1999).

1.3. Physical Properties of Pure and Vegetable Oils Mixtures.

Physical properties such as density, refractive index, extinction coefficient, polarizability, specific rotation, thermal expansion, viscosity and surface tension are widely used in measuring the concentration of most binary oil mixtures (Varde, 1984; Esteban *et al.*, 2012; Rudan Tasic and Klofutar, 1999). These physical properties give useful analytical information for industrial and healthy purposes.

In optics the refractive index or index of refraction *n* of a substance (optical medium) is a dimensionless number that describes how light, or any other radiation, propagates through that medium. It is defined as $n = c/v$, where c is the speed of light in vacuum and v is the speed of light in the substance (Meeteen, 1999). For example, the refractive index of water is 1.33, meaning that light travels 1.33 times slower in water than it does in vacuum. The historically first occurrence of the refractive index was in Snell's law of refraction, $n_1 \sin\theta_1 = n_2 \sin\theta_2$, where θ_1 and θ_2 are the angles of incidence of a ray crossing the interface between two media with refractive indices n_1 and n_2. Wavelength (Thormahlen *et al*., 1985), temperature (Thormahlen *et al*., 1985; Mehra, 2003), pressure (Weiss *et al*., 2012) and concentration (Subedi *et al*., 2006) are most important factors affecting on refractive index of pure and liquid mixtures.

Refractive index is measured for many reasons. It is clearly important to know the refractive index of materials used for their clarity, such as glasses and solid plastics. In complex fluids such as drinks or foods, the refractive index is a measure of dissolved or submicronic material (Singh *et al.*, 2013). Common industrial applications are to microemulsions to measure their oil/water ratio, to antifreeze to check the glycol/water ratio, and to inaccessible liquids such as the electrolyte of rechargeable cells. The clinical applications of light have stimulated interest in biotissue

refractometry, the refractometry is useful for the analysis of small samples of biofluids (Lin *et al.*, 1999). Refractive index can be measured by deferent technical methods such as interferometry, deviation, critical angle, Brewster angle, index match, microscopy and scattering (Meeteen, 1999).

The empirical relationship between refractive index and wave length of incident light for a transparent material is called Cauchy's equation (CE). The coefficients of Cauchy's equation can be determined for a material by fitting the equation to the measured refractive indices at known wavelengths (Bashkatov and Genina, 2002).The Cauchy's equation coefficients were determined for many liquid substances (Li and Wu, 2004). In particular, the Cauchy's equation is only valid for regions of normal dispersion in the visible wavelength region. In the infrared, the equation becomes inaccurate, and it cannot represent regions of anomalous dispersion. Different refractive index mixing rules such as Lorentz Lorenz equation (LLE), Clausius Mossotti relation (CMR), Arago Biot equation (ABE), Newton equation (NE), Maxwell's formula (MF), Gladstone Dale relation (GDR), Heller relation (HR), Eyring and John equation (EJE), Eykman relation (EE), Oster relation (OR) and Wiener relation (WR) are most frequently employed to test the validity of the experimental results (Wankhede, 2012). The most widely used theoretical mixing rules for predicting refractivity of pure and binary liquid mixtures are due to Lorentz–Lorenz equation and Weiner relation (Mehra, 2003; Wankhede, 2012; Narendra *et al.*, 2011; Wiederseiner *et al.*, 2011). The famous Lorentz Lorenz equation links the density and the refractive index of a liquid using the polarizability (Weiss *et al.*, 2012). This empirical relationship was given a sounder theoretical basis by H. A. Lorentz (1880) and L. V. Lorenz (1880), who calculated independently from the electromagnetic theory of light that the quantity $[(n^2-1)/(n^2+2)](1/\rho)$ should be a constant (Barer and Joseph,1954). Temperature independent quantity, specific refraction (R_D) that characterizes electric polarizability of a substance was calculated by Lorentz and Lorenz equation as follows (Deosarkar *et al.*, 2013):

$$R_D = \frac{(n_D^2 - 1)}{(n_D^2 + 2)} \times \frac{1}{\rho} \cdots\cdots\cdots (1.1)$$

Where ρ is the density and n_D is the D-line refractive index. Beysens and Calmettes (1977) discuss the deviations from Lorentz – Lorenz for the temperature dependence of the refractive indices of liquids. Li *et al*. (1994) proposed a modified Lorentz – Lorenz equation for the temperature and concentration dependence of refractive index of liquid mixtures. For a given wavelength Gladstone - Dale found experimentally that $(n-1)/\rho$ was almost independent of temperature for many liquids (Barer and Joseph, 1954). Polarizability is a property of matter, which can measure the ability for the molecules to be, polarized (Khodier, 2002). Polarizabilities of

substances determine the dynamical response of a bound system to external electric fields, and provide insight into a molecule's internal structure. There are several scientific reports available on the refractive index of pure vegetable oils (Rudan Tasic and Klofutar, 1999; Ariponnammal, 2012) and its mixtures (Ariponnammal, 2012). It is known that the VLS range dispersion relation of optical material could be accurately fitted by the Cauchy empirical formula (Khodier, 2002):

$$n(\lambda) = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} \cdots\cdots\cdots (1.2)$$

Where A, B and C are the fitting constants at a given concentration (c), temperature (T) and wave length (λ). The Cauchy's constants of olive oil have been reported by (Al-Dergazly).

We can see in a general way that the refractive index of a substance is related to its density. A light wave passing through an empty space will encounter no atoms, and it will proceed with unchanged velocity. If the same space is now partially filled with atoms or molecules, the incident wave will interact with these as described above, so that its velocity will be reduced. It is reasonable to assume that since the reduction in velocity is the result of the interaction between the light and atoms in its path, the refractive index will depend on the number of the latter per unit length, or in other words on the density (Barer and Joseph,1954). In liquid mixtures or solutions with concentration c, the specific refractive index increment dn/dc is an important parameter in light scattering measurements, which can be used for the determination of molecular weight, size, and shape (Van Krevelen, 1972). Barer and Joseph (1954) have pointed out that the value of the specific refractive index increment may vary with the nature of the solvent.

Ariponnammal (2012) proposed a novel method of using refractive index as a tool for finding the adultration of oils. The Ariponnammal study reveals that the simple laboratory measurement of refractive index can be used as a quality control technique for finding the adultration of vegetable oils. At optical high frequencies the permittivity of a material cannot be measured by the use of electrical methods. However, it is known from Maxwell’s theory for electromagnetic waves that for non-magnetic materials the permittivity is related to the refractive index as follows (Kumar and Singh, 2010):

$$n^2 = \varepsilon \cdots\cdots\cdots (1.3)$$

Using the data of refractive index and according to Maxwell’s theory for transparent non-magnetic materials (permeability ≈1), we are able to calculate the optical permittivities (ε) at the mentioned wavelengths (Tekin and Tarimci, 2006).

Viscosity is one of the most important physical properties of a fluid system. In the food industry, viscosity is one of the most important

parameters required in the design of technological process. On the other side, viscosity is also an important factor that determines the overall quality and stability of a food system. From the physicochemical point of view, viscosity means the resistance of one part of the fluid to move relative to another one. Viscosity changes with shear rate, temperature, pressure, moisture, and concentration; all these changes can be modelled by equations. The relationship between viscosity and temperature for vegetable oils has been studied by (Giap, 2010) and by (Fasina and Colley, 2008). It is well known that the activation energy for Newtonian viscous flow can be easily calculated Arrhenius type relationship. (Babaee, 2007) used the activation energy to compare between the effects of catalysts on the hydrogenation of soybean oil.

Most of liquid substances expand upon heating and contract when cooled. The change in volume ΔV with temperature ΔT for a substance can be expressed as (Maurya *et al.*, 2013):

$$\frac{\Delta V}{V_o} = \gamma_T \Delta T \quad \cdots\cdots\cdots (1.4)$$

The constant γ_T called the thermal expansion coefficient of the material. The thermal expansion coefficient can be determined from the thermal effect on volume, density, viscosity, electric permittivity or refractive index. Prod'homme proposed a theoretical equation to calculate optically the thermal expansion of liquids. The densities and thermal expansion coefficients of some vegetable oils has been reported by (Klofutar, 1997). Thermal expansion coefficients of a transparent substance can be defined optically using refractive index (Gupta *et al.*, 2012. Li, 2006) used the specific refraction of Lorentz Lorenz equation to calculate the thermal expansion coefficients. And Abramovic reported the regressional parameters of the polynomial relation described the effect of temperature on the density of camelina oil (Abramovic and Abram, 2005).
Mineral and vegetable oils and its mixtures have been studied to use in electrical insulation systems and heat transfer equipements such as transformers, capacitors, bushings etc (Bertrand and Hoang, 2004). Many countries are increasingly interested in producing straight vegetable oil (SVO) for direct use as fuel in diesel engines for stationary applications in the fields of agriculture, power generation and industry. Straight vegetable oil fuel quality, i.e impurities content and physico-chemical properties, is a recurring issue that seriously impedes the development of the sector. However, there is still no standard defining the quality characteristics of vegetable oils and its mixtures for fuel purposes in stationary engines (Blin *et al.*, 2013). Some other experimental and theoretical investigations reports that vegetable oils and its mixtures can be successfully used as an active laser material and as new photonic liquid crystal for optical

communication systems due to its nonlinear optical properties (Al-Dergazly and Fadhel, 2007).

To evaluate the range of convergence between the calculated and measured values we can use the mean relative error MRE. The mean relative error can be calculated by (Bashkatov and Genina, 2002):

$$MRE = \frac{|f_{meas} - f_{cal}|}{f_{meas}} \quad \text{..........} (1.5)$$

Where f_{meas} is the measured physical value and f_{cal} is the corresponding calculated physical value.

1.4. Aims of this Study.

The aims of our recent study can be summarized in the following points:

1. Measuring and calculating the physical quantities of olive/corn oil mixtures and olive/acetone solutions such as refractive index, specific refraction, density, viscosity, thermal expansion and activation energy.
2. Finding simplified methods for testing and detecting the concentrations of binary mixtures (olive/corn oil and olive/acetone).
3. Finding the empirical formula that can describe the relation between refractive index, specific refraction, density, viscosity, thermal expansion and activation energy with concentration and temperature.
4. Finding the empirical formula that can describe the relation between temperature gradient of refractive index, specific refraction, density, viscosity, thermal expansion and activation energy with concentration and temperature.
5. Comparing the accuracy between the applying of the following mixing rule equations of Lorentz Lorenz, Arago Biot, Newton, Gladstone Dale and Eyring John using the measured values of refractive index and density.
6. Calculating the values of specific refraction for all temperatures and concentrations using the modeling equations of Lorentz Lorenz, Gladstone Dale, Eykman, Newton, Oster and Arago Biot.
7. Verification that the specific refraction is independent on temperature for all theoretical modeling equations.
8. Comparing the accuracy between the applying of Andrade and Vogel equations using the measured values of dynamic viscosity.
9. Calculating the coefficients of thermal expansion using volumetric and optical methods.

CHAPTER TWO
EXPERIMENTAL PROCEDURE

Tin liquid samples were prepared by mixing different weights of olive and corn oils to give ten concentrations (0%, 10%, 20%, 30% --- 90%, 100%) and seven liquid samples were prepared by dissolving different weights of olive oil in acetone to give seven concentrations (5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%). The greater the concentration of acetone caused greater proportions of the volatilization of it. And in order to reduce the volatility of acetone; the oil/acetone samples were prepared with acetone concentration lower than 40%. The liquid mixtures were prepared by mass in an air light stopped bottle using an electronic balance (model OHAUS E400 accurate to within ±0.01g). The refractive indices of the samples at the visible D spectral line (Na, λ = 589nm, see Figure (1.1)) were obtained with a high-accuracy Abbe refractometer (MEDLINE model CONVEX, see Figure (1.2) in the temperature range from 292.15 to 324.15^{o}K (19-51^{o}C). The temperature of the Abbes refractometer cell was controlled by a circulating thermostated bath (Grant Instruments), see Figure (1.3).

The density of the liquid mixtures, which is required to determine other physical properties, was measured from 19 to 51^{o}C by a pycnometric method (Pycnometer volume 25mL, see Figure (1.4)). The dynamic viscosities of all samples were measured using falling ball viscometer (HAAKE, Germany, see Figure (1.5)). The radian of the used balls in viscometer is (11.08, 14.28, 15.25, 15.62, 15.67 and 15.83mm) and the length of the falling ball tube is 15cm. The thermal expansion coefficients of all liquid samples were obtained using expansion thermometer with spherical bulb of radius 1.73cm and capillary tube with radius 1.5mm (see Figure (1.6)).



Figure (1.3): Circulating Thermostated Bath.



Figure (1.2) Abbe Refractometer.



Figure (1.1): Sodium Lamp.

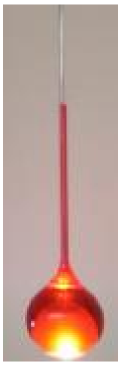


Figure (1.6): Expansion Thermometer.



Figure (1.5): Falling Ball Viscometer



Figure (1.4): Pycnometer.

CHAPTER THREE
RESULTS AND DISCUSSION

3.1. Refractive Index and its Temperature Gradient of Olive/Corn Oils and Olive/Acetone Mixtures.

Refractive index of liquid mixtures and solutions is fundamentally interesting and practically useful parameter. In addition to the molecular constituents, the wavelength, temperature and concentration are the most important factors affecting the refractive indices of liquid mixtures and solutions. Prediction of refractive indices of binary liquid mixtures is essential for the determination of composition of binary liquid mixtures (Mehra, 2003). Refractive index measurements in combination with density, viscosity, thermal expansion and other analytical data are very useful healthy and industrially also for common substances which include oils, waxes, sugar syrups etc. An exhaustive literature survey reveals that there is no such data on these systems, the components of which have wide applicability in chemical analyses and industry. The variation for the magnitude of the refractive index n as a function of temperature, or the thermal coefficient of the refractive index, dn/dT, is a very important property for photonic materials and devices. It plays vital role in many areas of material science with special regarding to thin film technology, integrated optics, waveguide optics and fiber optics. The refractive index of liquid mixtures or solutions changed with concentration; that change can be characterized by specific refractive increment. Knowledge of specific refractive increment of organic liquid substances is important for the determination of molecular weights by light-scattering measurements (Barer, 1954). The refractive index can be measured with a much higher degree of accuracy than permittivity ε; in many cases the measurement of optical and electrical properties of a substance can be replaced by measuring the refractive index. Furthermore, thermal coefficient of the n can also be used to calculate thermal expansion coefficient. As we know, the refractive index of a medium depends on the density of the medium as well as temperature. With the decrease in solution concentration, the density of the solution decreases, resulting in a decrease in refractive index. Recently, there are many works on investigating dn/dT and dn/dc of different materials (Chen *et al.*, 2008). The refractive indices of all olive/Corn oils and olive/acetone mixture samples were measured by Abbe refractometer in the temperature range from 292.15 - 324.15^{o}K (19-51^{o}C) using the monochromatic visible D spectral line of sodium (λ=589nm). Figure (3.1.1) shows the experimental results of the refractive index versus temperature at 0%, 10%, 20%, 30% --- 90%, 100% concentrations of olive/corn mixtures, respectively. Figure (3.1.2) shows the experimental results of the refractive index versus temperature at 5%, 10%, 15%, 20%,

25%, 30%, 35%, 40% concentrations of olive/acetone solutions, respectively. From figures (3.1.1) and (3.1.2) we can notice that the refractive index decreased linearly with increasing temperature for all concentrations. This effect can be explained by the link between the behavior of all of refractive index and density with heat. It means that the refractive index decreased with the decreasing of density; which caused by the increasing of temperature. Raising the temperature of samples may lead a break in some chemical bonds in the organic materials consisting of oil or may caused enlarging the space between molecules in it. This effect of temperature changes the space between the molecules which can change the velocity of light passing through it and accordingly changed the refractive index of the liquid mixture. Also we can observe from figure (3.1.1) that the refractive index increased with decreasing olive oil concentration.

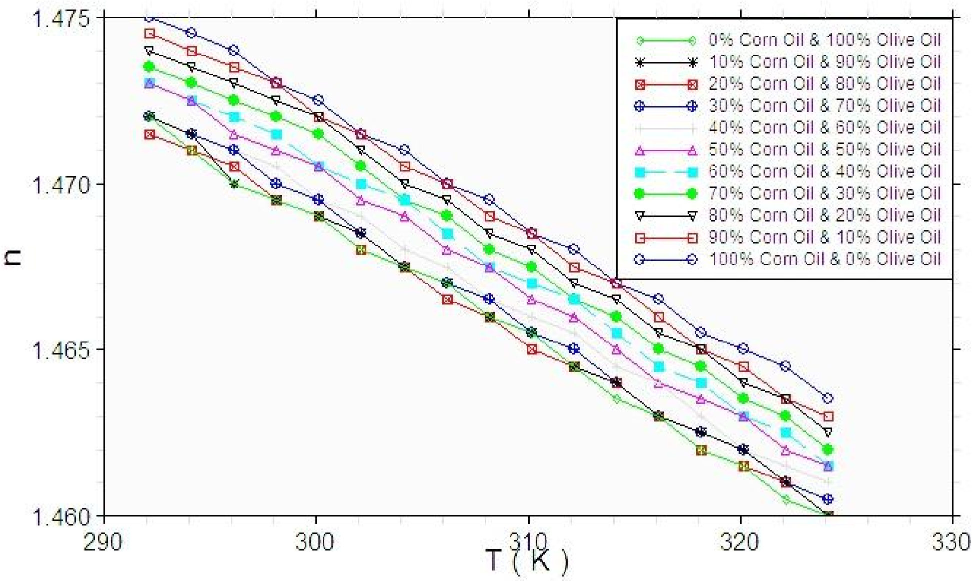


Figure (3.1.1):
Refractive index versus temperature for different concentrations of olive/corn oil mixtures.

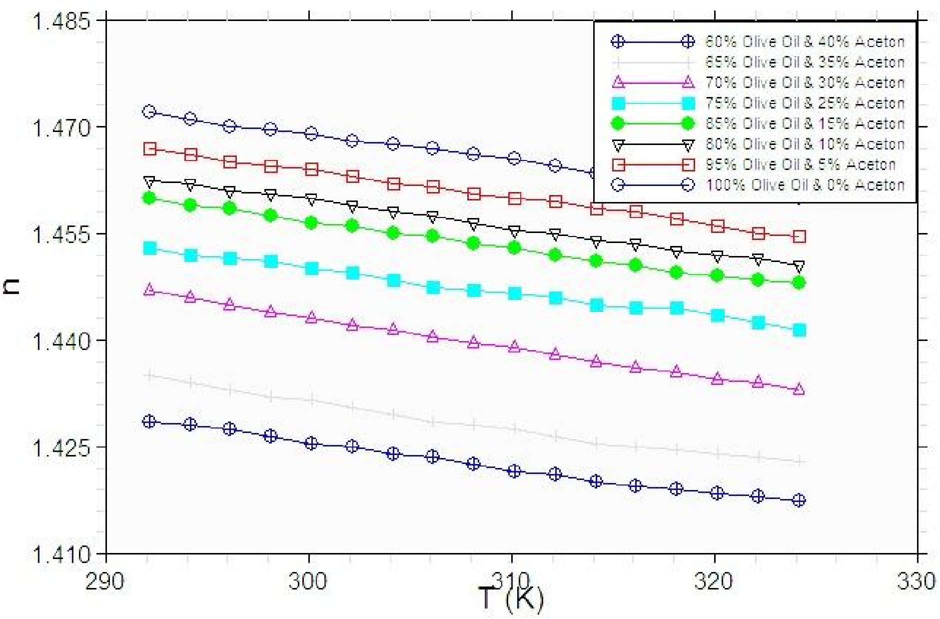


Figure (3.1.2):
Refractive index versus temperature for different concentrations of olive/acetone solutions.

Barer (1954) have pointed out that the refractive index may vary with the nature of solvent. All solvents with lower refractive index and lower molecular weight can decrease the refractive index of liquids with a high refractive index and high molecular weight. In our study we used acetone as a solvent and it is clearly seen from figure (3.1.2) that acetone decreased the refractive index of olive oil. The values of refractive index for concentrations ranged between 1.460 and 1.475 for olive/corn oil mixtures and between 1.416 and 1.473 for olive/acetone solutions. In most instances the usefulness of the refractive index is its ability to indicate, indirectly, something about the state or structure of the material under consideration. In our case; the refractive index can indirectly measured the concentration of oil/oil mixtures or the concentration of oil/solvent solutions. There are several reported attempts in the literature to develop empirical equations that yield the index of refraction of oil/oil mixtures and oil/solvent solutions as a function of several parameters such as temperature, concentration and wavelength. Since we are interested in the index of refraction of olive/corn mixtures and olive/acetone solutions, the following polynomial equations will be useful. The effect of temperature on refractive index could be accurately fitted by the polynomial equation (Muhammad *et al.*, 2008):

$$n = A_{on} + B_{on}T + C_{on}T^2 \quad \cdots\cdots\cdots (3.1.1)$$

The fitting constants A_{on}, B_{on}, and C_{on} are given in tables (3.1.1) and (3.1.2) for all concentrations of olive/corn oil mixtures and olive/acetone solutions.

Table (3.1.1)

The fitting constants of the polynomial equation of refractive index versus temperature for all concentrations of olive/corn oil mixtures.

MRE	C_{on} (T^{-2})	B_{on} (T^{-1})	A_{on}	Percentage of Concentration
0.001679	-4.84×10^{-8}	-3.36×10^{-4}	1.58	100% Corn Oil & 0% Olive Oil
0.000403	-1.20×10^{-6}	3.65×10^{-4}	1.47	90% Corn Oil & 10% Olive Oil
0.00144	-1.37×10^{-6}	4.76×10^{-4}	1.45	80% Corn Oil & 20% Olive Oil
0.0011	-1.37×10^{-6}	4.76×10^{-4}	1.45	70% Corn Oil & 30% Olive Oil
0.001148	-1.89×10^{-6}	7.97×10^{-4}	1.4	60% Corn Oil & 40% Olive Oil
0.001411	-5.16×10^{-7}	-3.33×10^{-4}	1.48	50% Corn Oil & 50% Olive Oil
0.001769	-1.05×10^{-6}	2.89×10^{-4}	1.48	40% Corn Oil & 60% Olive Oil
0.000433	-4.61×10^{-11}	-3.71×10^{-4}	1.58	30% Corn Oil & 70% Olive Oil
0.000338	-2.90×10^{-7}	-1.85×10^{-4}	1.55	20% Corn Oil & 80% Olive Oil
0.002884	-4.59×10^{-7}	-7.96×10^{-5}	1.53	10% Corn Oil & 90% Olive Oil
0.001226	-1.33×10^{-6}	4.56×10^{-4}	1.45	0% Corn Oil & 100% Olive Oil

Table (3.1.2)

The fitting constants of the polynomial equation of refractive index versus temperature for all concentrations of olive/acetone solutions.

MRE	C_{on} (T^{-2})	B_{on} (T^{-1})	A_{on}	Percentage of Concentration
0.001217205	-5.32×10^{-7}	-5.50×10^{-5}	1.53	5% Acetone& 95% Olive Oil
0.000421033	2.74×10^{-7}	-5.52×10^{-5}	1.6	10% Acetone& 90% Olive Oil
0.002803035	1.52×10^{-6}	-0.00132	1.72	15% Acetone& 85% Olive Oil
0.001191635	7.90×10^{-7}	-8.31×10^{-5}	1.63	25% Acetone& 75% Olive Oil
0.00183687	1.61×10^{-6}	-0.00143	1.73	30% Acetone& 70% Olive Oil
8.21284×10^{-5}	4.06×10^{-6}	-0.00288	1.93	35% Acetone& 65% Olive Oil
0.000393494	2.50×10^{-6}	-0.0019	1.77	40% Acetone& 60% Olive Oil

The temperature gradients of refractive index dn/dT for all concentrations of olive/corn oil mixtures and olive/acetone solutions are shown respectively in figures (3.1.3) and (3.1.4). These linear temperature gradients were fitted by a polynomial equation:

$$\frac{dn}{dT} = A_n + B_n T + C_n T^2 \cdots\cdots\cdots (3.1.2)$$

Where $A_n = B_{on}$ and $B_n = 2C_{on}$. The constants of the polynomial equation of temperature gradient for all concentrations of olive/corn oil mixtures and

olive/acetone solutions were shown respectively in tables (3.1.3) and (3.1.4).

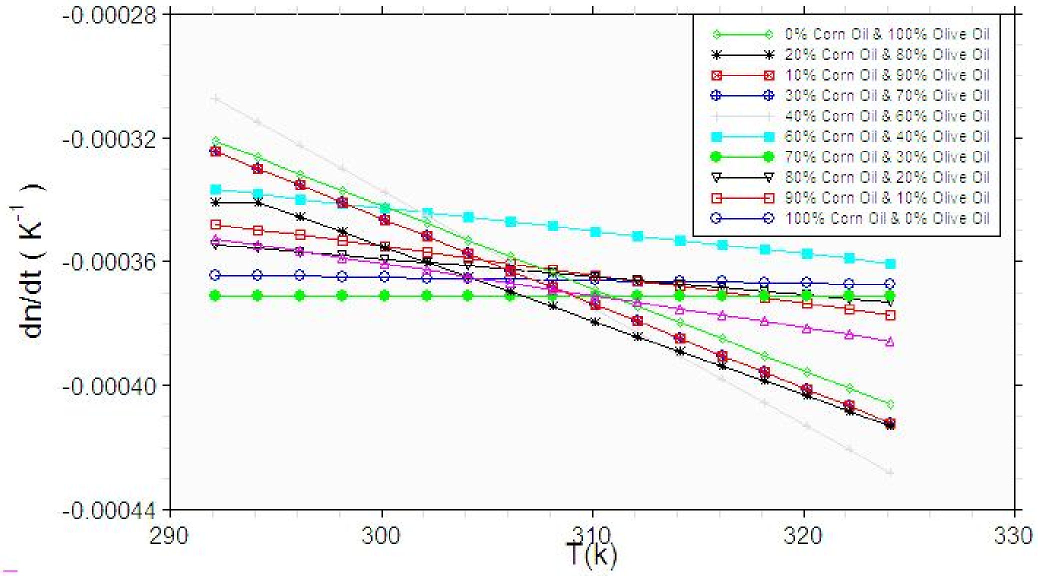


Figure (3.1.3)
The temperature gradients of refractive index for all concentrations of olive/corn oil mixtures.

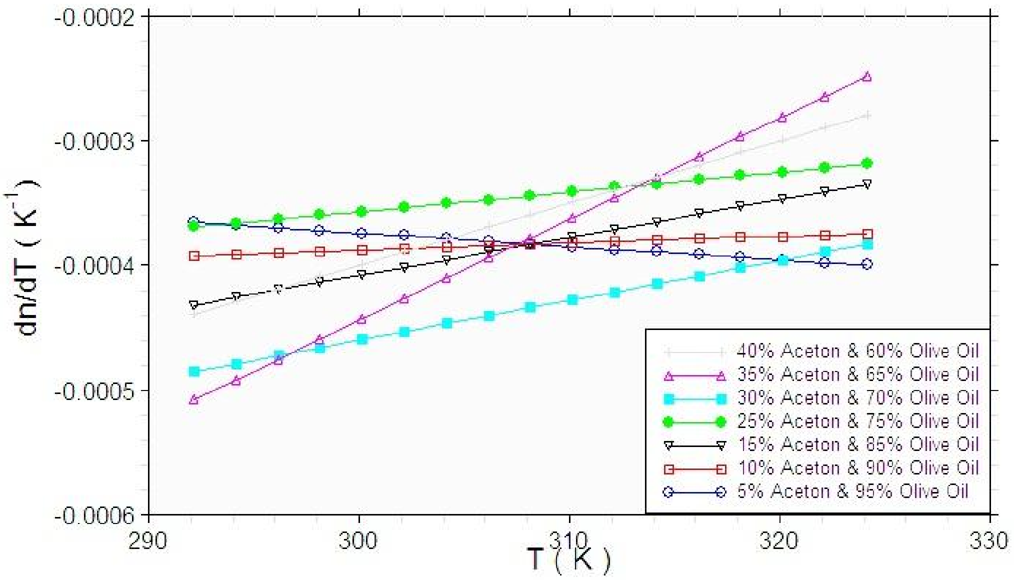


Figure (3.1.4)
The temperature gradients of refractive index for all concentrations of olive/acetone solutions.

Table (3.1.3)
The constants of the polynomial equation of temperature gradient of refractive index for all concentrations of olive/corn oil mixtures.

MRE	C_n (K^{-3})	B_n (K^{-2})	A_n (K^{-1})	Percentage of Concentration
1.4117×10^{-5}	5.35×10^{-14}	-9.68×10^{-8}	-0.00034	100% Corn Oil & 0% Olive Oil
3.0423×10^{-6}	-3.56×10^{-18}	-2.40×10^{-6}	0.000365	90% Corn Oil & 10% Olive Oil
3.05178×10^{-6}	-5.63×10^{-15}	-2.74×10^{-6}	0.000476	80% Corn Oil & 20% Olive Oil
0.000100215	6.57×10^{-14}	-4.00×10^{-6}	0.000526	70% Corn Oil & 30% Olive Oil
1.10596×10^{-5}	1.31×10^{-14}	-3.78×10^{-6}	0.000797	60% Corn Oil & 40% Olive Oil
0.001678201	1.13×10^{-14}	-1×10^{-6}	-5.1×10^{-5}	50% Corn Oil & 50% Olive Oil
3.30452×10^{-6}	-3.94×10^{-14}	-7.42×10^{-7}	-0.00012	40% Corn Oil & 60% Olive Oil
1.4437×10^{-6}	-4.23×10^{-13}	1.59×10^{-10}	-0.00037	30% Corn Oil & 70% Olive Oil
1.4437×10^{-6}	1.13×10^{-14}	-5.80×10^{-7}	-0.00019	20% Corn Oil & 80% Olive Oil
0.005453832	-1.13×10^{-14}	-9.18×10^{-7}	-8×10^{-5}	10% Corn Oil & 90% Olive Oil
5.35432×10^{-6}	-2.06×10^{-14}	-2.66×10^{-6}	0.000456	0% Corn Oil & 100% Olive Oil

Table (3.1.4)
The constants of the polynomial equation of temperature gradient of refractive index for all concentrations of olive/acetone solutions.

MRE	C_n (K^{-3})	B_n (K^{-2})	A_n (K^{-1})	Percentage of Concentration
0.003216551	-1.13×10-14	-1.06E-06	-5.50×10-5	5% Acetone& 95% Olive Oil
5.18512×10^{-11}	2.09×10-19	5.48×10-7	-5.52×10-4	10% Acetone& 90% Olive Oil
2.55475×10^{-6}	-1.03×10-14	3.04×10-6	-0.00132	15% Acetone& 85% Olive Oil
5.19287×10^{-7}	-1.88×10-15	1.58×10-6	-8.31×10-4	25% Acetone& 75% Olive Oil
3.08868×10^{-6}	1.41×10-14	3.20×10-6	-0.00142	30% Acetone& 70% Olive Oil
3.54728×10^{-6}	1.41×10-14	8.12×10-6	-0.00288	35% Acetone& 65% Olive Oil
2.77815×10^{-10}	-1.05×10-18	5.00×10-6	-0.0019	40% Acetone& 60% Olive Oil

3.2. Density and its Temperature Gradient of Olive/Corn Oils and Olive/Acetone Mixtures.

Density was determined picnometrically according to official method of the association of analytical communities (AOAC) at temperatures ranging from 292.15 - 324.15^{o}K. The accuracy of density determination was about 10^{-4} g/mL. The density in the temperature range 292.15 - 324.15^{o}K for all concentrations of olive/corn oil mixtures and olive/acetone solutions were shown respectively in figures (3.2.1) and (3.2.2).

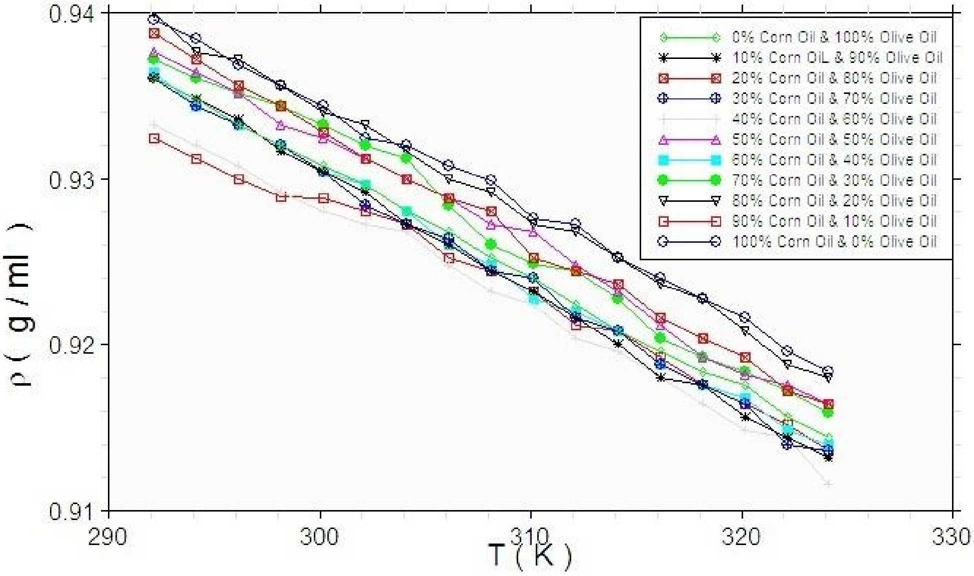


Figure (3.2.1)
The density in the temperature range 292.15 - 324.15^{o}K for all concentrations of olive/corn oil mixtures.

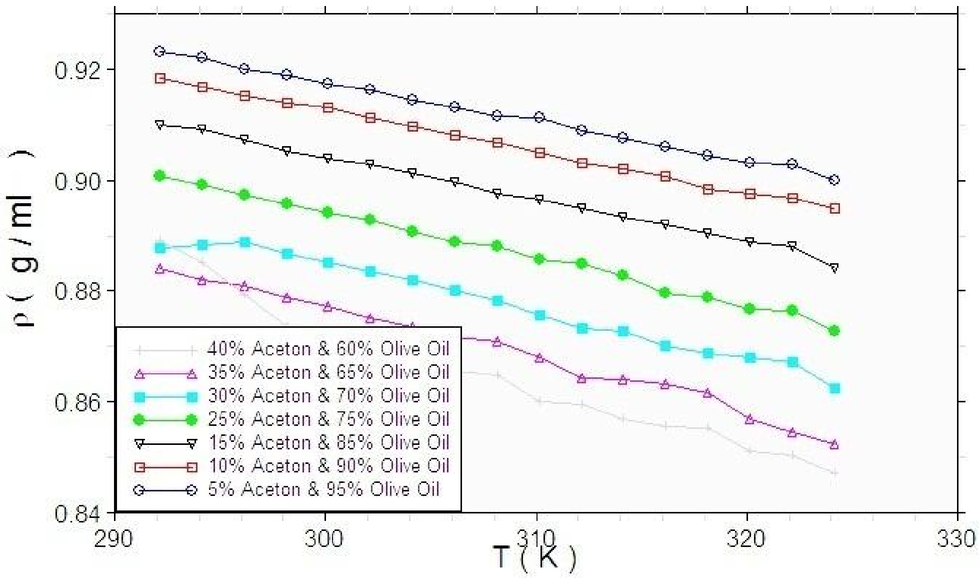


Figure (3.2.2)
The density in the temperature range 292.15 - 324.15^{o}K for all concentrations of olive/acetone solutions.

It is clearly seen from figures that the density for all concentrations decreased linearly with increasing temperature, that is because the enlarging of spaces between the molecules of oil. From figure (3.2.1) we can notice that corn oil dense than olive oil. The values of density for all concentrations ranged between 0.911g/mL and 0.940g/mL for olive/corn oil mixtures and between 0.845g/mL and 0.923g/mL for olive/acetone solutions. From figure (3.2.2) we can see that the density of olive/acetone solution decreased with increasing acetone concentration. Since the density

of acetone less than olive oil, any addition of acetone will reduce the density of olive/acetone solution. The effect of temperature on density could be accurately fitted by polynomial equation (Musso *et al.*, 2000):

$$\rho = A_{o\rho} + B_{o\rho}T + C_{o\rho}T^2 \cdots\cdots\cdots (3.2.1)$$

The fitting constants $A_{o\rho}$, $B_{o\rho}$, and $C_{o\rho}$ are given in tables (3.2.1) and (3.2.2) for all concentrations of olive/corn oil mixtures and olive/acetone solutions.

Table (3.2.1)

The fitting constants of the polynomial equation of density versus temperature for all concentrations of olive/corn oil mixtures.

MRE	**$C_{o\rho}$ (g/mLK^2)**	**$B_{o\rho}$ (g/mLK)**	**$A_{o\rho}$ (g/mL)**	**Percentage of Concentration**
0.000275	-1.51×10^{-6}	2.78×10^{-4}	0.987	100% Corn Oil & 0% Olive Oil
0.001112	-6.46×10^{-6}	3.40×10^{-3}	0.489	90% Corn Oil & 10% Olive Oil
0.003845	-1.19×10^{-6}	5.99×10^{-5}	1.02	80% Corn Oil & 20% Olive Oil
0.000588	-2.00×10^{-6}	5.26×10^{-4}	0.955	70% Corn Oil & 30% Olive Oil
0.000941	-3.60×10^{-6}	1.56×10^{-3}	0.783	60% Corn Oil & 40% Olive Oil
0.00059	-2.23×10^{-6}	6.96×10^{-4}	0.925	50% Corn Oil & 50% Olive Oil
0.001712	-3.60×10^{-6}	1.56×10^{-3}	0.783	40% Corn Oil & 60% Olive Oil
0.001467	-4.39×10^{-7}	-4.38×10^{-4}	1.1	30% Corn Oil & 70% Olive Oil
0.002746	6.84×10^{-7}	-1.12×10^{-3}	1.21	20% Corn Oil & 80% Olive Oil
0.003736	5.99×10^{-7}	-1.10×10^{-3}	1.21	10% Corn Oil & 90% Olive Oil
0.000931	-1.42×10^{-7}	-5.91×10^{-4}	1.12	0% Corn Oil & 100% Olive Oil

Table (3.2.2)

The fitting constants of the polynomial equation of density versus temperature for all concentrations of olive/acetone solutions.

MRE	**$C_{o\rho}$** (g/mLK^2)	**$B_{o\rho}$** (g/mLK)	**$A_{o\rho}$** (g/mL)	**Percentage of Concentration**
0.001001126	1.29×10^{-8}	-7.15×10^{-4}	1.13	5% Acetone& 95% Olive Oil
0.003136572	3.35×10^{-7}	-9.49×10^{-4}	1.17	10% Acetone& 90% Olive Oil
0.003090213	-1.32×10^{-6}	3.44×10^{-5}	1.01	15% Acetone& 85% Olive Oil
6.84661×10^{-5}	-1.99×10^{-6}	3.75×10^{-4}	0.961	25% Acetone& 75% Olive Oil
0.00138567	-6.94×10^{-6}	0.00344	0.476	30% Acetone& 70% Olive Oil
0.000796991	-7.21×10^{-6}	0.00348	0.483	35% Acetone& 65% Olive Oil
0.008398742	1.93×10^{-5}	-0.0131	3.06	40% Acetone& 60% Olive Oil

The temperature gradients of density dρ/dT for all concentrations of olive/corn oil mixtures and olive/acetone solutions are shown respectively in figures (3.2.3) and (3.2.4). These linear temperature gradients were fitted by a polynomial equation:

$$\frac{d\rho}{dT} = A_{\rho} + B_{\rho}T + C_{\rho}T^2 \cdots\cdots\cdots (3.2.2)$$

Where $A_{\rho} = B_{o\rho}$ and $B_{\rho} = 2C_{o\rho}$. The constants of the polynomial equation of temperature gradient for all concentrations of olive/corn oil mixtures and olive/acetone solutions were shown respectively in tables (3.2.3) and (3.2.4).

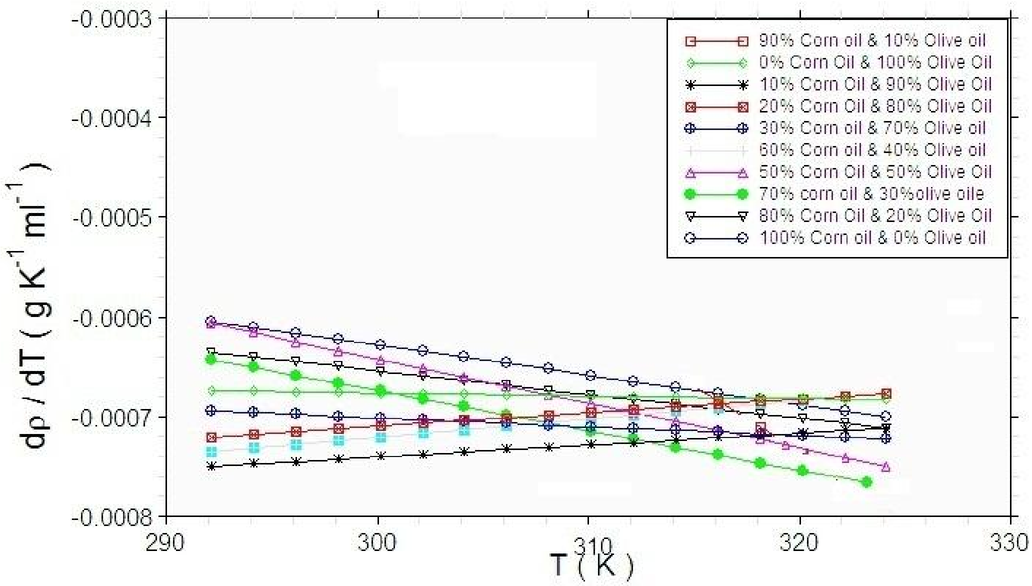


Figure (3.2.3)
The temperature gradients of density for all concentrations of olive/corn oil mixtures.

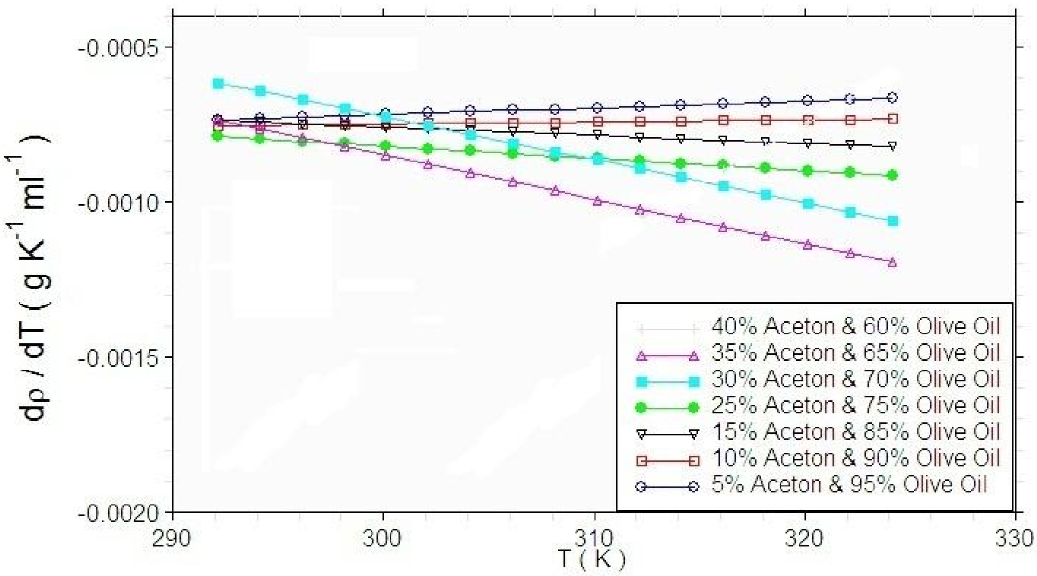


Figure (3.2.4)
The temperature gradients of density for all concentrations of olive/acetone solutions.

Table (3.2.3)
The constants of the polynomial equation of temperature gradient of density for all concentrations of olive/corn oil mixtures.

MRE	C_ρ (g/mLK^3)	B_ρ (g/mLK^2)	A_ρ (g/mLK)	Percentage of Concentration
1.92×10^{-10}	1.32×10^{-18}	-3.02×10^{-6}	0.000278	100% Corn Oil & 0% Olive Oil
0.004288	1.65×10^{-14}	-1.29×10^{-5}	0.0034	90% Corn Oil & 10% Olive Oil
2.65×10^{-7}	-2.38×10^{-6}	-2.38×10^{-6}	5.99×10^{-5}	80% Corn Oil & 20% Olive Oil
8.84×10^{-6}	-5.63×10^{-15}	-2.74×10^{-6}	0.000476	70% Corn Oil & 30% Olive Oil
0.000874	-1.06×10^{-18}	1.83×10^{-6}	-0.00127	60% Corn Oil & 40% Olive Oil
4.47×10^{-6}	-3.19×10^{-14}	-4.46×10^{-6}	0.000696	50% Corn Oil & 50% Olive Oil
0.000874	-3.28×10^{-14}	-3.60×10^{-6}	0.00156	40% Corn Oil & 60% Olive Oil
6.29×10^{-6}	4.69×10^{-14}	-8.78×10^{-7}	-0.00044	30% Corn Oil & 70% Olive Oil
0.000877	-4.13×10^{-14}	1.37×10^{-6}	-0.00112	20% Corn Oil & 80% Olive Oil
0.000843	-3.62×10^{-18}	1.20×10^{-6}	-0.0011	10% Corn Oil & 90% Olive Oil
3.36×10^{-6}	-2.82×10^{-14}	-2.84×10^{-7}	-0.00059	0% Corn Oil & 100% Olive Oil

Table (3.2.4)
The constants of the polynomial equation of temperature gradient of density for all concentrations of olive/acetone solutions.

MRE	C_ρ (g/mLK^3)	B_ρ (g/mLK^2)	A_ρ (g/mLK)	Percentage of Concentration
2.55377×10^{-7}	1.88×10^{-15}	2.24×10^{-6}	-0.00139	5% Acetone& 95% Olive Oil
1.53612×10^{-10}	-1.20×10^{-18}	6.70×10^{-7}	-9.49×10^{-4}	10% Acetone& 90% Olive Oil
6.41722×10^{-11}	-5.26×10^{-19}	-2.64×10^{-6}	3.44×10^{-5}	15% Acetone& 85% Olive Oil
4.39852×10^{-6}	3.94×10^{-14}	-3.98×10^{-6}	3.75×10^{-4}	25% Acetone& 75% Olive Oil
0.007359358	2.44×10^{-14}	-1.39×10^{-5}	0.00344	30% Acetone& 70% Olive Oil
0.006390764	-5.63×10^{-14}	-1.44×10^{-5}	0.00348	35% Acetone& 65% Olive Oil
1.033×10^{-5}	-1.31×10^{-13}	3.86×10^{-5}	-0.0131	40% Acetone& 60% Olive Oil

3.3. Viscosity, Temperature Gradient of Viscosity and Activation Energy of Olive/Corn Oils and Olive/Acetone Mixtures.

In the food industry, viscosity is one of the most important parameters required in the design of technological process. On the other side, viscosity is also an important factor that determines the overall quality and stability of a food system. From the physicochemical point of view, viscosity means the resistance of one part of the fluid to move relative to another one. Therefore, viscosity must be closely correlated with the structural parameters of the fluid particles. On the basis of published data concerning flow properties of oils, the oil viscosity has a direct relationship with some chemical characteristics of the lipids, such as the degree of unsaturation and the chain length of the fatty acids that constitute the triacylglycerols. The viscosity slightly decreases with increased degree of unsaturation and rapidly increases with polymerization (Abramovic and Klofutar, 1998). Dynamic or absolute viscosity η can be obtained by multiplying the kinematic viscosity of fluid ν by its mass density (Neelamgam and Krishnaraj, 2011).

$$\eta = \rho v \cdots\cdots\cdots (3.3.1)$$

Dynamic viscosity is defined as the ratio of shear stress τ (force over cross section area) to the rate of deformation γ (the difference of velocity over a sheared distance), and it is presented as:

$$\eta = \frac{\tau}{du/_{dx}} = \frac{\tau}{\gamma} \cdots\cdots\cdots (3.3.2)$$

The dynamic viscosity in the temperature range 19 to 51°C for all concentrations of olive/corn oil mixtures and olive/acetone solutions were shown respectively in figures (3.3.1) and (3.3.2).

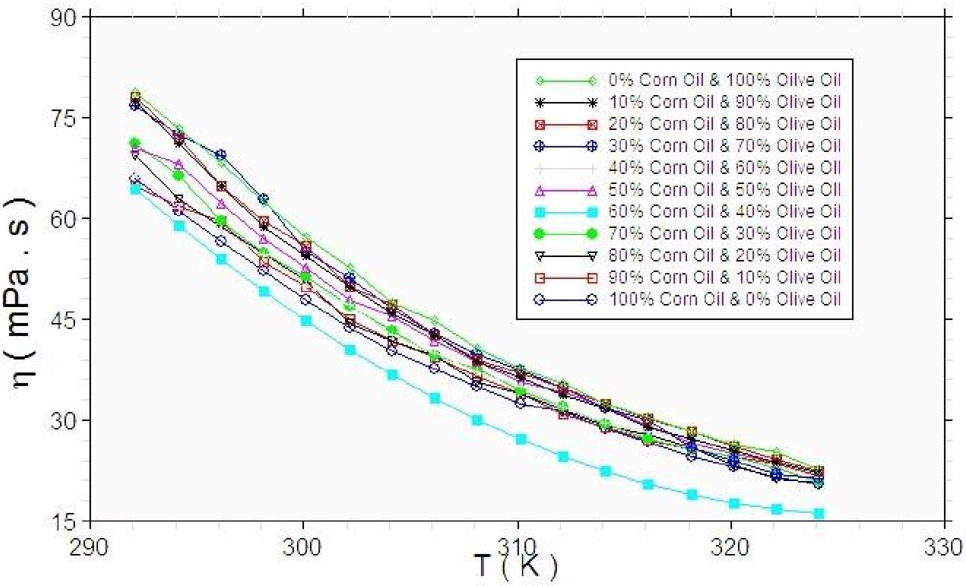


Figure (3.3.1)
The dynamic viscosity in the temperature range 19 to 51°C for all concentrations of olive/corn oil mixtures.

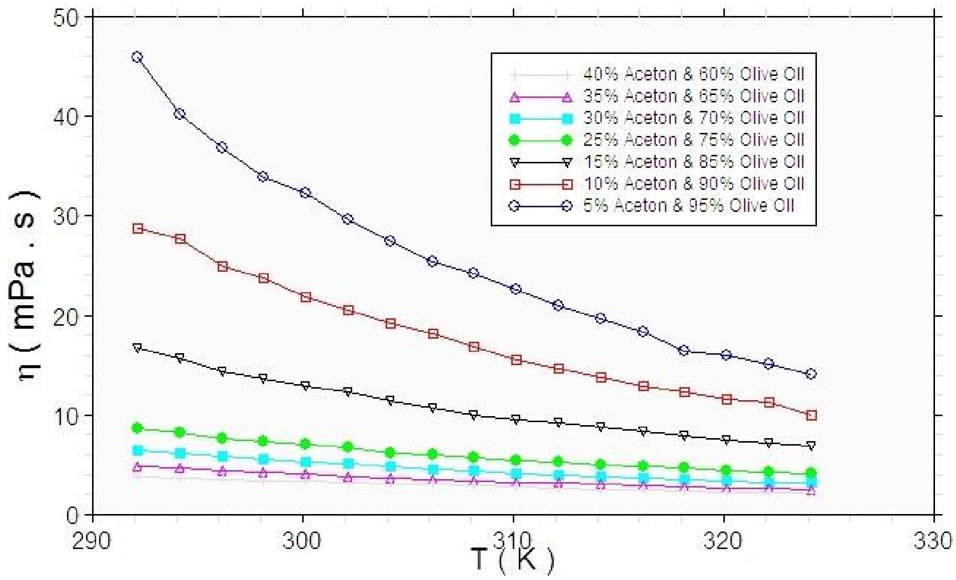


Figure (3.3.2)
The dynamic viscosity in the temperature range 19 to 51°C for all concentrations of olive/acetone solutions.

Viscosity is influenced by the molecular properties of liquids such as vegetable oils. There is a direct relationship between the chain length and degree of saturation of the fatty acids that form triaclyglycerols. Generally speaking saturated oils are more viscous than unsaturated oils. Unsaturated oils have double bonds in the hydrocarbon chains, whereas saturated oils feature more single bonds and attached hydrogen atoms. The linear "zigzag" structure of saturated fatty acid hydrocarbon chains enables the molecules to line up and form intermolecular Van der Waals interactions, reducing their viscosity. Unsaturated hydrocarbon chains have double bonds that produce "kinks" in the molecule. These "kinks" prevent the molecules getting as close to each other and forming as many Van der Waals interactions, thus increasing the viscosity of the oil. From figures (3.3.1) and (3.3.2) we can notice that the dynamic viscosity or absolute viscosity η decreased linearly with increasing temperature for all concentrations. In figures (3.3.1) and (3.3.2) we can see that the dynamic viscosity increased with increasing olive oil concentration which means that the viscosity of olive oil higher than corn oil. High viscosity of olive oil is due to a high concentration of monosaturated fatty acids in it (Abramovic and Klofutar, 1998). It is clearly observed from the last graph that the change in dynamic viscosity increased with increasing olive oil concentration. In the samples with low concentration of olive oil the dynamic viscosity nearly independent on temperature. Also we can observe from figure (3.3.2) that the change in dynamic viscosity decreased with increasing temperature and it becomes none observed at the temperature higher than 320^{o}K. The values of dynamic viscosity for all concentrations ranged between 16mPa.s and 79mPa.s for olive/corn oil mixtures and between 4mPa.s and 46mPa.s for olive/acetone solutions. The effect of temperature on viscosity could be accurately fitted by polynomial equation:

$$\eta = A_{o\eta} + B_{o\eta} T + C_{o\eta} T^2 \quad \cdots\cdots\cdots (3.3.3)$$

The fitting constants $A_{o\eta}$, $B_{o\eta}$, and $C_{o\eta}$ are given in tables (3.3.1) and (3.3.2) for all concentrations of olive/corn oil mixtures and olive/acetone solutions.

Table (3.3.1)

The fitting constants of the polynomial equation of dynamic viscosity versus temperature for all concentrations of olive/corn oil mixtures.

MRE	**$C_{o\eta}$ (mPa.s/K^2)**	**$B_{o\eta}$ (mPa.s/K)**	**$A_{o\eta}$ (mPa.s)**	**Percentage of Concentration**
0.050369	0.0318	-21	3485	100% Corn Oil & 0% Olive Oil
0.032914	0.0335	-22.1	3650	90% Corn Oil & 10% Olive Oil
0.53352	0.0327	-21.7	3600	80% Corn Oil & 20% Olive Oil
0.465425	0.0359	-23.7	3915	70% Corn Oil & 30% Olive Oil
0	0.0392	-25.7	4248	60% Corn Oil & 40% Olive Oil
0.438167	0.0315	-21	3503	50% Corn Oil & 50% Olive Oil
0.18556	0.0278	-18.5	3105	40% Corn Oil & 60% Olive Oil
0.368608	0.0368	-24.5	4082	30% Corn Oil & 70% Olive Oil
0.301637	0.0409	-26.9	4434	20% Corn Oil & 80% Olive Oil
0.34444	0.0415	-27.2	4493	10% Corn Oil & 90% Olive Oil
0.164196	0.0399	-26.3	4363	0% Corn Oil & 100% Olive Oil

Table (3.3.2)

The fitting constants of the polynomial equation of dynamic viscosity versus temperature for all concentrations of olive/acetone solutions.

MRE	**$C_{o\eta}$** (mPa.s/K^2)	**$B_{o\eta}$** (mPa.s/K)	**$A_{o\eta}$** (mPa.s)	**Percentage of Concentration**
0.256258145	0.0216	-14.2	2355	5% Acetone& 95% Olive Oil
0.102772116	0.0112	-7.47	1257	10% Acetone& 90% Olive Oil
0.038912167	0.00644	-4.27	714	15% Acetone& 85% Olive Oil
0.238186563	0.00246	-1.65	282	25% Acetone& 75% Olive Oil
0.027415388	0.00178	-1.2	205	30% Acetone& 70% Olive Oil
0.197293429	0.00116	-0.79	136	35% Acetone& 65% Olive Oil
0.003651666	2.86×10^{-4}	-0.229	46.3	40% Acetone& 60% Olive Oil

The temperature gradients of dynamic viscosity $d\eta/dT$ for all concentrations of olive/corn oil mixtures and olive/acetone solutions are shown respectively in figures (3.3.3) and (3.3.4). These linear temperature gradients were fitted by a polynomial equation:

$$\frac{d\eta}{dT} = A_\eta + B_\eta T + C_\eta T^2 \cdots\cdots\cdots (3.3.4)$$

Where $A_\eta = B_{o\eta}$ and $B_\eta = 2C_{o\eta}$. The constants of the polynomial equation of temperature gradient for all concentrations of olive/corn oil mixtures and olive/acetone solutions were shown respectively in tables (3.3.3) and (3.3.4).

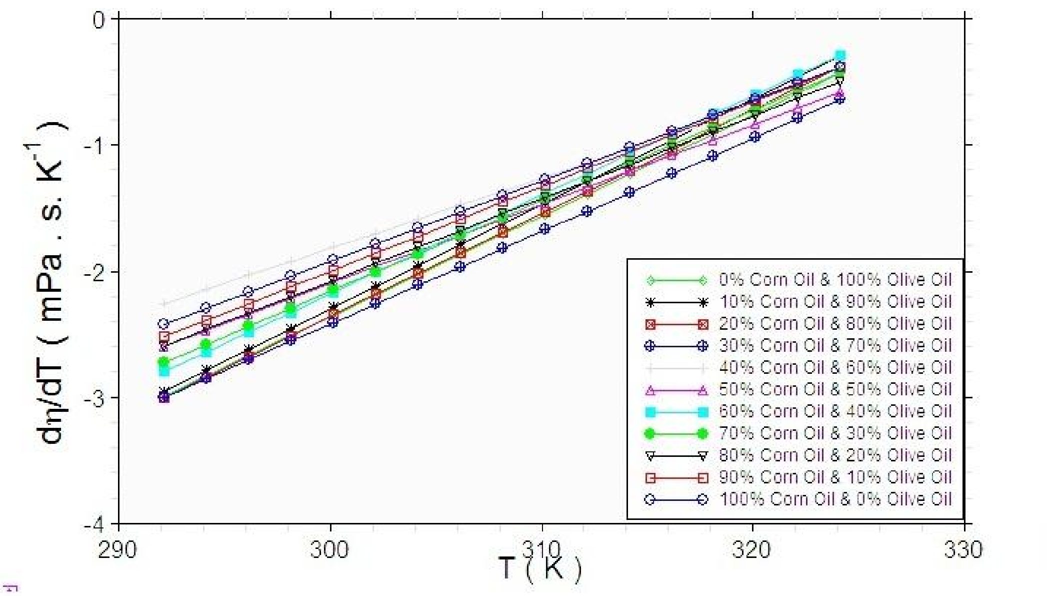


Figure (3.3.3)
The temperature gradients of dynamic viscosity for all concentrations of olive/corn oil mixtures.

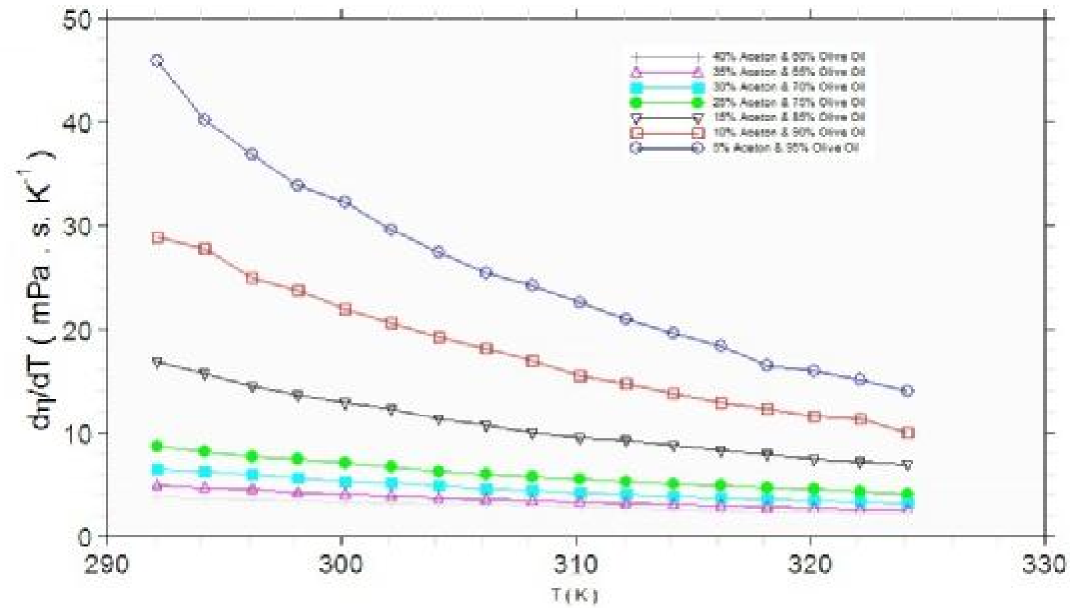


Figure (3.3.4)
The temperature gradients of dynamic viscosity for all concentrations of olive/acetone solutions.

Table (3.3.3)
The constants of the polynomial equation of temperature gradient of dynamic viscosity for all concentrations of olive/corn oil mixtures.

MRE	**C_η (mPa.s/K^3)**	**B_η (mPa.s/K^2)**	**A_η (mPa.s/K)**	**Percentage of Concentration**
4.96×10^{-6}	-7.3×10^{-11}	0.0636	-21	100% Corn Oil & 0% Olive Oil
0.010311	1.45×10^{-10}	0.067	-22.1	90% Corn Oil & 10% Olive Oil
8.29×10^{-6}	1.35×10^{-10}	0.0654	-21.7	80% Corn Oil & 20% Olive Oil
5.11×10^{-6}	8.46×10^{-11}	0.0718	-23.7	70% Corn Oil & 30% Olive Oil
9.87×10^{-6}	1.6×10^{-10}	0.0784	-25.7	60% Corn Oil & 40% Olive Oil
7.61×10^{-6}	1.27×10^{-10}	0.063	-21	50% Corn Oil & 50% Olive Oil
2.68×10^{-7}	-3.9×10^{-12}	0.0556	-18.5	40% Corn Oil & 60% Olive Oil
1.81×10^{-6}	-3.5×10^{-11}	0.0736	-24.5	30% Corn Oil & 70% Olive Oil
6.79×10^{-6}	-1.2×10^{-10}	0.0818	-26.9	20% Corn Oil & 80% Olive Oil
2.24×10^{-7}	3.83×10^{-12}	0.083	-27.2	10% Corn Oil & 90% Olive Oil
1.59×10^{-5}	2.86×10^{-10}	0.0798	-26.3	0% Corn Oil & 100% Olive Oil

Table (3.3.4)
The constants of the polynomial equation of temperature gradient of dynamic viscosity for all concentrations of olive/acetone solutions.

MRE	C_η (mPa.s/K^3)	B_η (mPa.s/K^2)	A_η (mPa.s/K)	Percentage of Concentration
0	0.0216	-14.2	2355	5% Acetone& 95% Olive Oil
0.334231075	0.0113	-7.51	1264	10% Acetone& 90% Olive Oil
0.154681167	0.00515	-3.48	592	15% Acetone& 85% Olive Oil
0.081424315	0.00205	-1.4	243	25% Acetone& 75% Olive Oil
0.305355623	0.00153	-1.04	181	30% Acetone& 70% Olive Oil
0.059693433	9.93×10^{-4}	-0.685	120	35% Acetone& 65% Olive Oil
0.005018772	6.57×10^{-4}	-0.458	81.6	40% Acetone& 60% Olive Oil

The effect of temperature on dynamic viscosity can be used to calculate the activation energy of the viscous flow of pure and liquid mixtures by Frenkel Eyring equation (FEE) (Tipvarakarnkoon *et al.*, 2008). The activation energy controls the rate of molecular motion and therefore the flow of liquids; consequently, viscosity can be considered as a thermally activated process whose temperature dependence is given by the following empirical Arrhenius equation:

$$\eta = A exp\left[\frac{-E_a}{RT}\right] \cdots\cdots\cdots (3.3.5)$$

Where E_a is the activation energy, R is the ideal gas constant, T is the absolute temperature and A is a constant (Rubalya *et al.*, 2013). Figures (3.3.5) and (3.3.6) shows the activation energy for all concentrations of olive/corn oil mixtures and olive/acetone solutions. The effect of temperature on activation energy could be accurately fitted by polynomial equation:

$$E_a = A_E + B_E T + C_E T^2 \cdots\cdots\cdots (3.3.6)$$

The fitting constants A_E, B_E, and C_E are given in tables (3.3.5) and (3.3.6) for all concentrations of olive/corn oil mixtures and olive/acetone solutions.

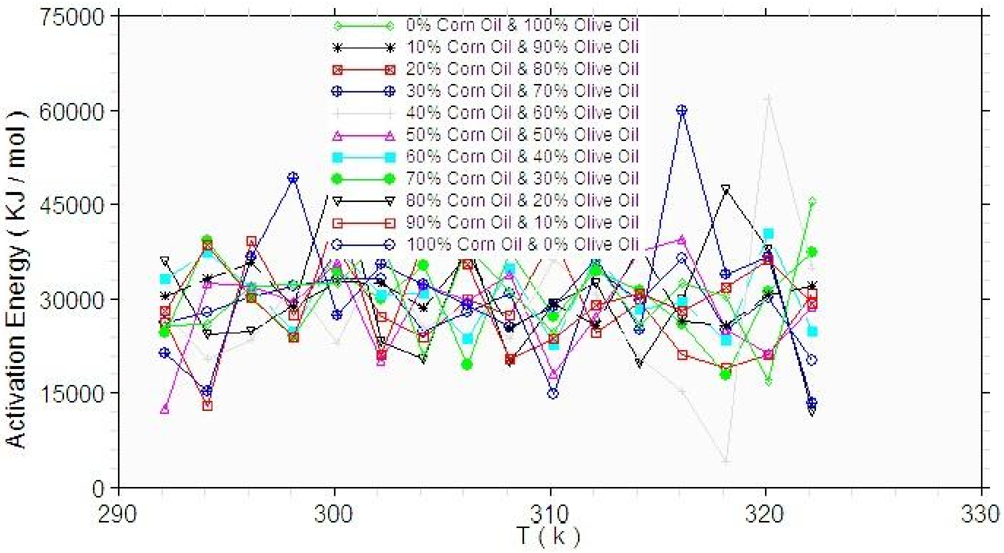


Figure (3.3.5)
The activation energy versus temperature for all concentrations of olive/corn oil mixtures.

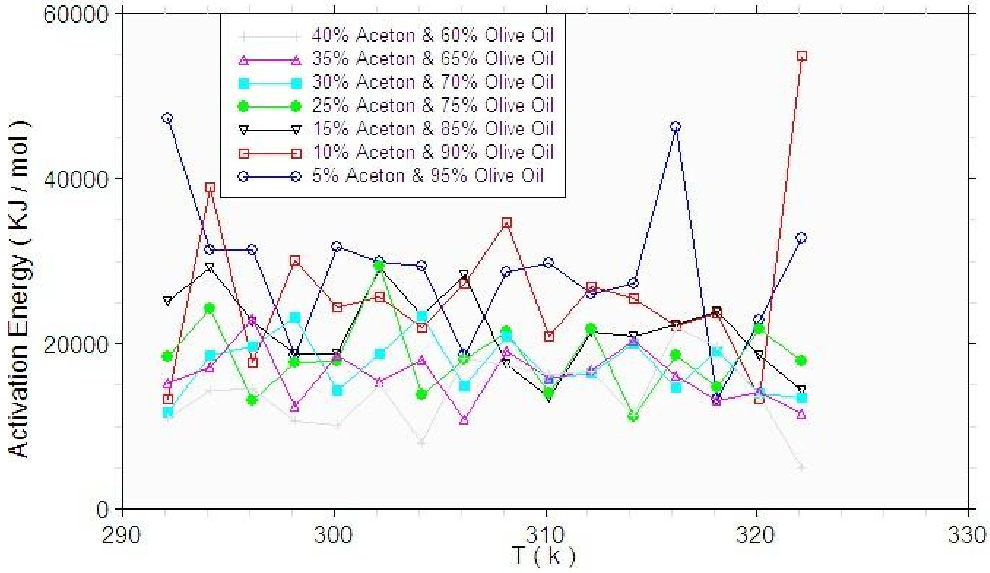


Figure (3.3.6)
The activation energy versus temperature for all concentrations of olive/acetone solutions.

Table (3.3.5)

The fitting constants of the polynomial equation of activation energy versus temperature for all concentrations of olive/corn oil mixtures.

C_E ($KJ/mol.K^2$)	B_E (KJ/mol.K)	A_E (KJ/mol)	Percentage of Concentration
-3.69	2338	-339000	100% Corn Oil & 0% Olive Oil
-32.2	19700	-2990000	90% Corn Oil & 10% Olive Oil
-3.89	2325	-317000	80% Corn Oil & 20% Olive Oil
3.89	-2421	406000	70% Corn Oil & 30% Olive Oil
10.8	-6790	1090000	60% Corn Oil & 40% Olive Oil
-27.9	17200	-2630000	50% Corn Oil & 50% Olive Oil
18.7	-11300	1730000	40% Corn Oil & 60% Olive Oil
-44.8	27600	-4230000	30% Corn Oil & 70% Olive Oil
12.8	-7927	1250000	20% Corn Oil & 80% Olive Oil
4.34	-2775	473000	10% Corn Oil & 90% Olive Oil
-3.69	2338	-339000	0% Corn Oil & 100% Olive Oil

Table (3.3.6)

The fitting constants of the polynomial equation of activation energy versus temperature for all concentrations of olive/acetone solutions.

C_E ($KJ/mol.K^2$)	B_E (KJ/mol.K)	A_E (KJ/mol)	Percentage of Concentration
34.4	-2.14×10^4	3.34×10^6	5% Acetone& 95% Olive Oil
19.7	-1.19×10^4	1.81×10^6	10% Acetone& 90% Olive Oil
-0.737	218	2.43×10^4	15% Acetone& 85% Olive Oil
2.78	-1778	3.02×10^5	25% Acetone& 75% Olive Oil
-20.1	1.23×10^4	-1.86×10^6	30% Acetone& 70% Olive Oil
-9.45	5698	-8.41×10^5	35% Acetone& 65% Olive Oil
-20	1.23×10^4	-1.89×10^6	40% Acetone& 60% Olive Oil

3.4. The Modeling of Refractive Index of Olive/Corn Oils and Olive/Acetone Mixtures Using Classic Empirical and Semi Empirical Equations of Mixing Rules.

It is often desirable to determine the index of refraction of solutions and liquid mixtures. This index can be estimated from the refractive indices of solution and solvent by using a suitable ‘‘mixture rule’’. In other wards the refractive index of any substance can possibly and easy determined theoretically knowing the volume fraction and refractive index of its pure components. (Mehra, 2003) pointed out the usefulness of mixing rules in determining binary refractive indices and density data. All theoretically derived rules are based upon the electromagnetic theory of light and can apply only if there is no change of volume during mixing (Wiederseiner *et al.*, 2011). The most classic equations include:

1. Lorentz Lorenz equation (Lorentz, 1906; Wiederseiner *et al.*, 2011; Sharma *et al.*, 2007):

$$\frac{n_{12}^2-1}{(n_{12}^2+2)\rho_{12}}=\left(\frac{n_1^2-1}{n_1^2+2}\right)\frac{\phi_1}{\rho_1}+\left(\frac{n_2^2-1}{n_2^2+2}\right)\frac{\phi_2}{\rho_2} \quad \text{..........} (3.4.1)$$

2. Gladstone Dale relation (Dale and Gladstone 1858, 1864; Wiederseiner *et al.*, 2011; Sharma *et al.*, 2007):

$$(n_{12}-1)\frac{1}{\rho_{12}} = (n_1-1)\frac{\phi_1}{\rho_1} + (n_2-1)\frac{\phi_2}{\rho_2} \cdots\cdots\cdots (3.4.2)$$

3. Arago Biot equation (Arago and Biot 1806; Wiederseiner *et al.*, 2011; Sharma *et al.*, 2007):

$$n_{12} = n_1\phi_1 + n_2\phi_2 \cdots\cdots\cdots (3.4.3)$$

4. Newton equation (Wiederseiner *et al.*, 2011; Sharma *et al.*, 2007):

$$n_{12}^2 = n_1^2\phi_1 + n_2^2\phi_2 \cdots\cdots\cdots (3.4.4)$$

5. Eyring John equation (Sharma *et al.*, 2007):

$$n_{12} = n_1\phi_1^2 + 2(n_1 n_2)^{\frac{1}{2}}\phi_1\phi_2 + n_2\phi_2^2 \cdots\cdots\cdots (3.4.5)$$

In all these equations, $\phi_1 = {x_1 V_1}/{\Sigma x_i V_i}$ and $\phi_2 = {x_2 V_2}/{\Sigma x_i V_i}$. Where n_{12} is the refractive index of mixture or solution, n_1 is the refractive index of the pure component 1, n_2 is the refractive index of the pure component 2, Φ_1 is the volume fraction of pure component 1, Φ_2 is the volume fraction of pure component 2, ρ_{12} is the density of mixture or solution, ρ_1 is the density of the pure component 1, ρ_2 is the density of the pure component 2, x_i is the mole fraction of the pure component i and V_i is the molar volume of the pure component i. The major drawback of these mixing rules is their inability to account for changes in volume and refractivity during mixing as they are based only on volume additivity (Mehra, 2003). Figures (3.4.1-10) shows the refractive index versus temperature for all concentrations of olive/corn oil mixtures and olive/acetone solutions using the mixtures rules of Lorentz-Lorenz equation, Gladstone-Dale relation, Arago-Biot equation, Newton equation and Eyring-John equation.

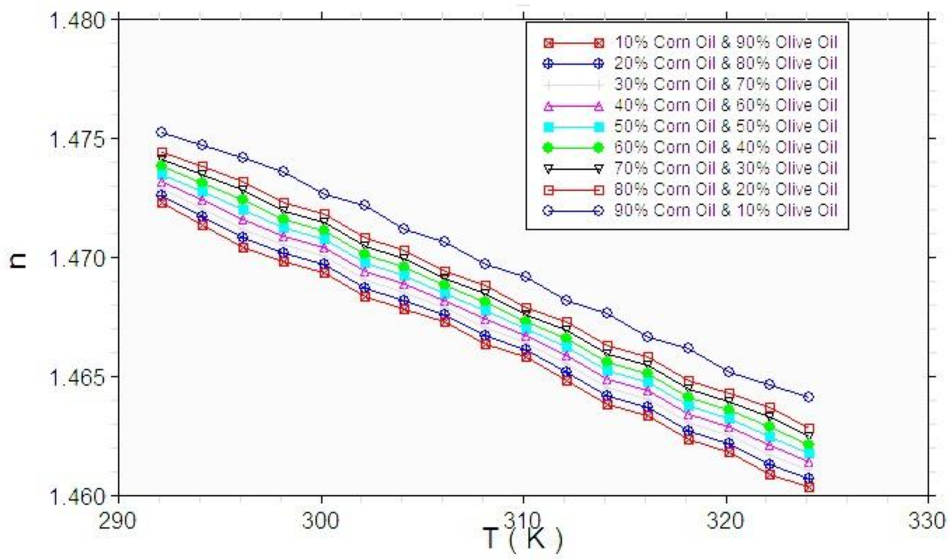


Figure (3.4.1)
Refractive index versus temperature calculated using Lorentz Lorenz equation for all concentrations of olive/corn oil mixtures.

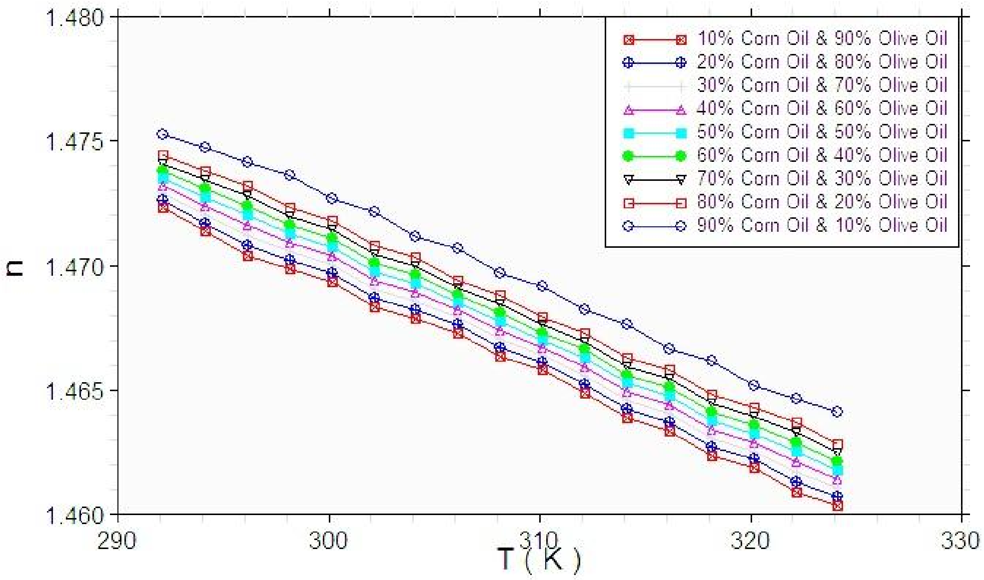


Figure (3.4.2)
Refractive index versus temperature calculated using Gladstone Dale relation for all concentrations of olive/corn oil mixtures.

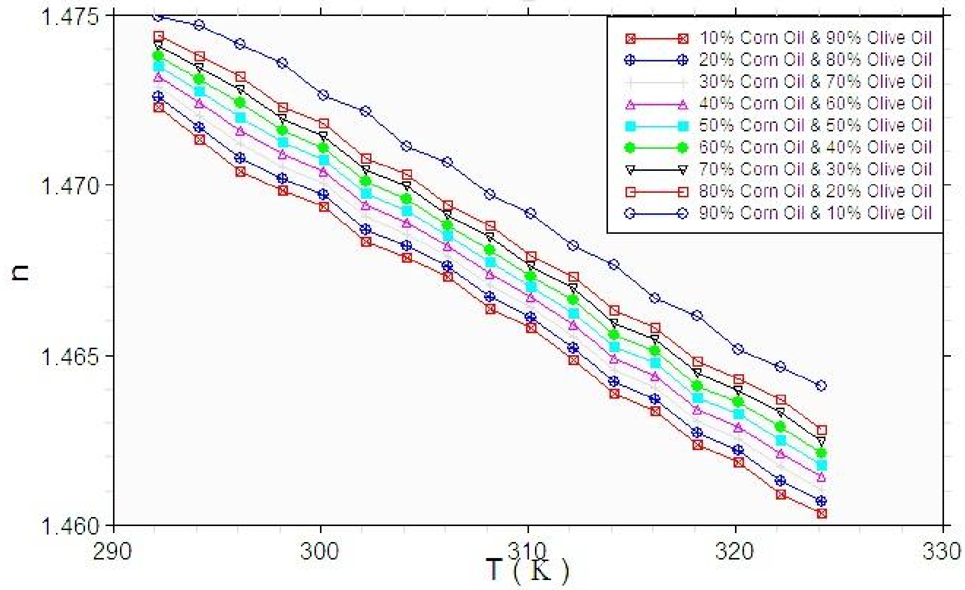


Figure (3.4.3)
Refractive index versus temperature calculated using Arago Biot equation for all concentrations of olive/corn oil mixtures.

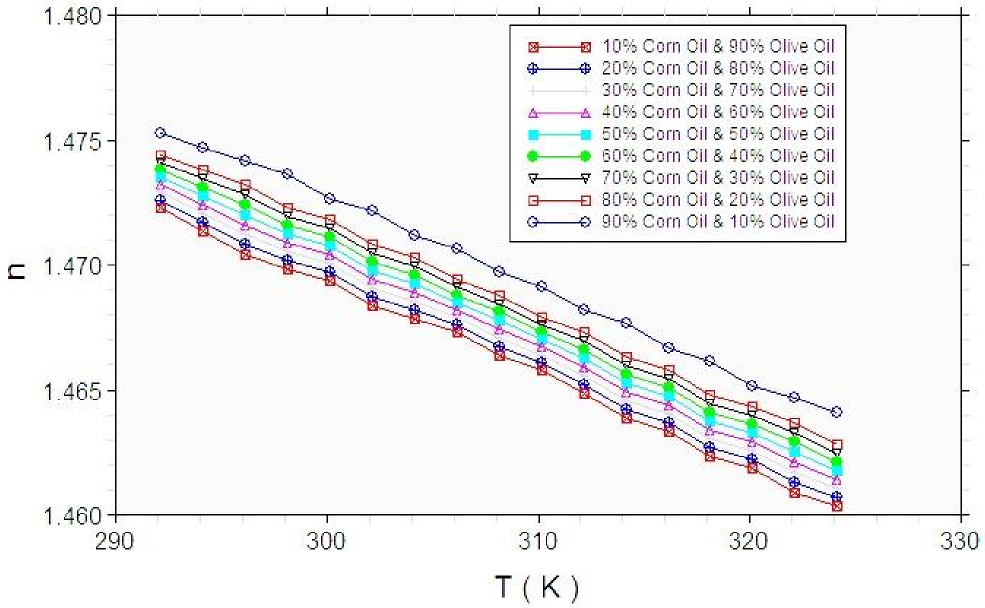


Figure (3.4.4)
Refractive index versus temperature calculated using Newton equation for all concentrations of olive/corn oil mixtures.

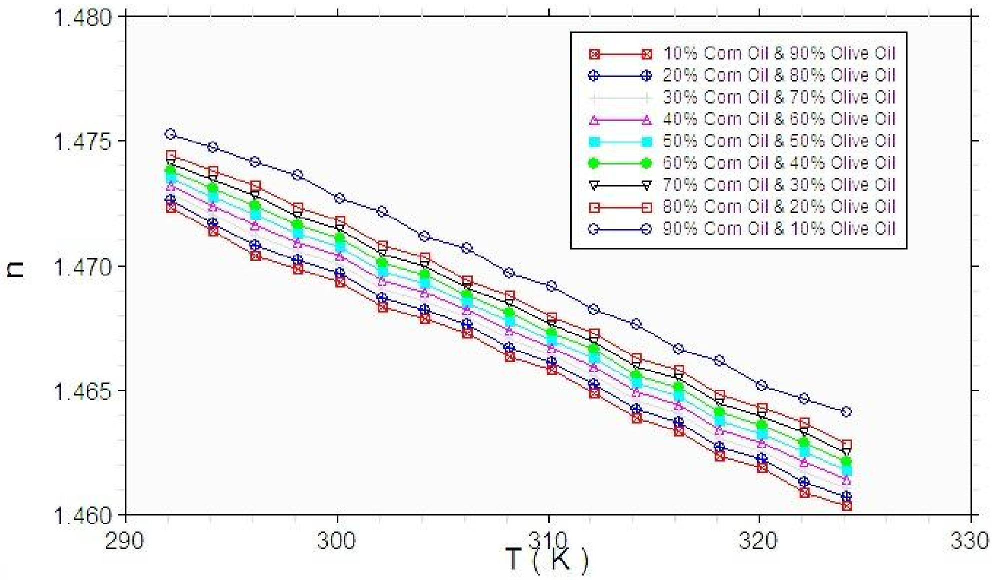


Figure (3.4.5)
Refractive index versus temperature calculated using Eyring John equation for all concentrations of olive/corn oil mixtures.

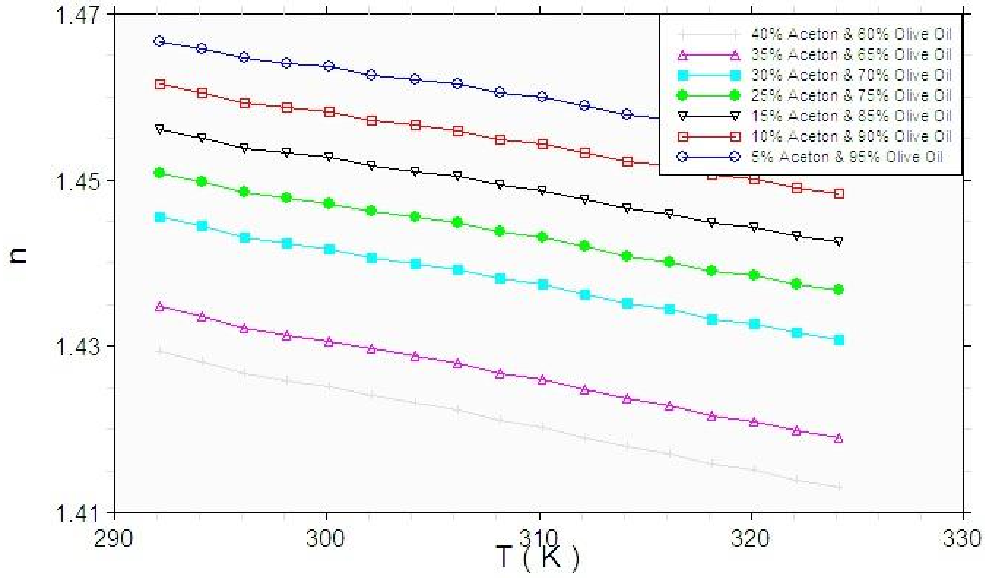


Figure (3.4.6)
Refractive index versus temperature calculated using Lorentz Lorenz equation for all concentrations of olive/acetone solutions.

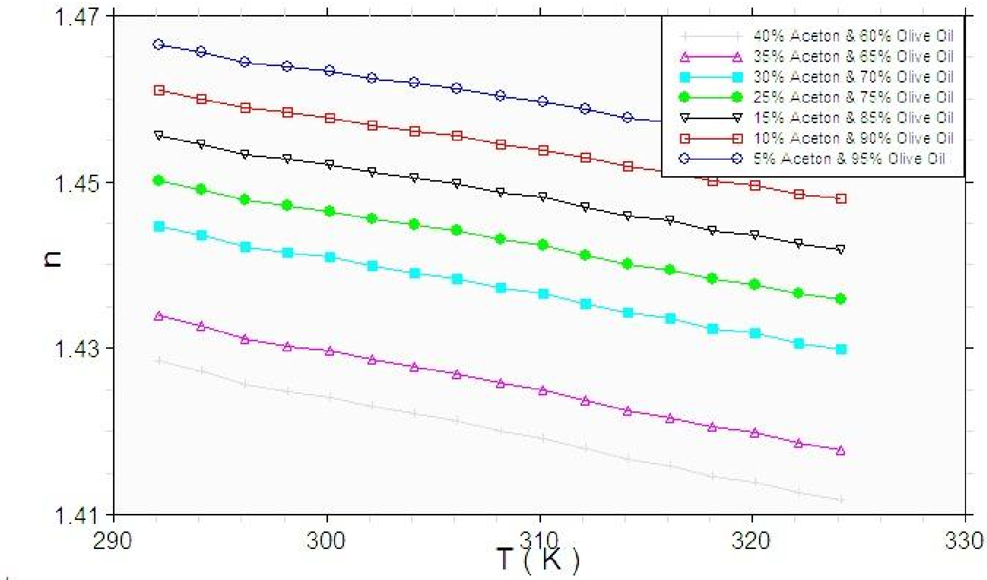


Figure (3.4.7)
Refractive index versus temperature calculated using Gladstone Dale relation for all concentrations of olive/acetone solutions.

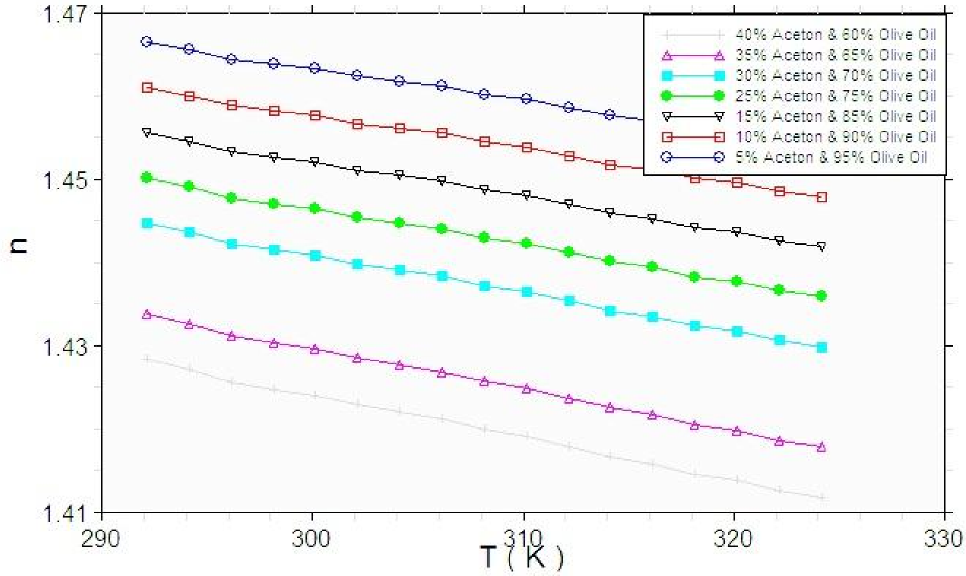


Figure (3.4.8)
Refractive index versus temperature calculated using Arago Biot equation for all concentrations of olive/acetone solutions.

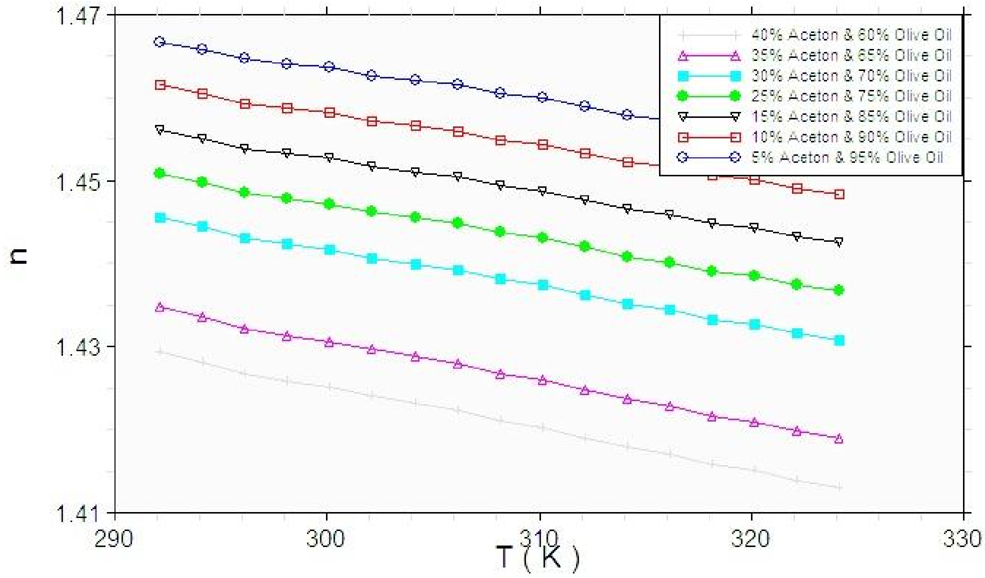


Figure (3.4.9)
Refractive index versus temperature calculated using Newton equation for all concentrations of olive/acetone solutions.

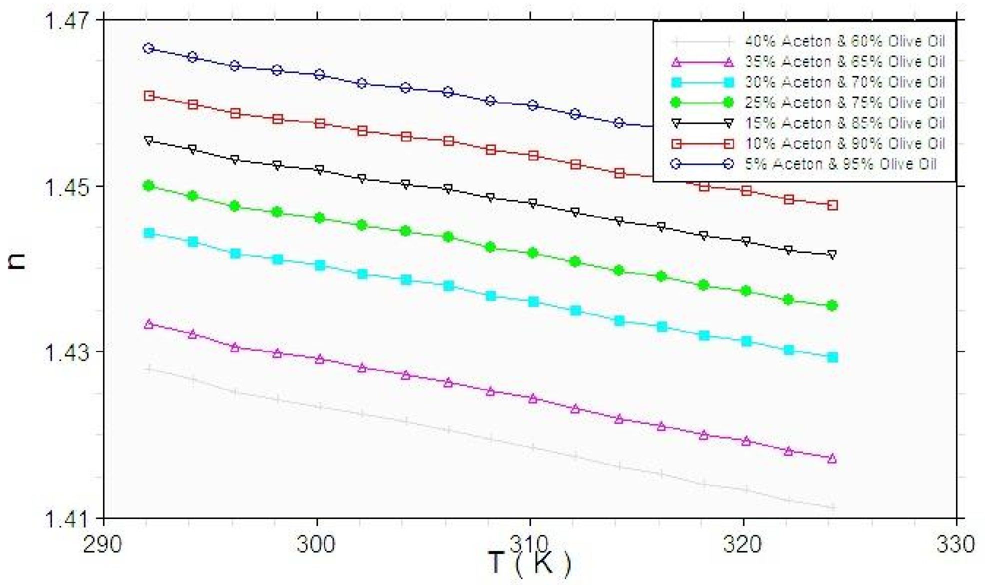


Figure (3.4.10)
Refractive index versus temperature calculated using Eyring John equation for all concentrations of olive/acetone solutions.

However, the deviations of theoretical values from experimental ones may be attributed to the fact that variation in refractive index with temperature is compensated for by the change in density of the liquid mixture.

In all the systems, refractive index values predicted from Newton relation shows excellent agreement with the experimental values followed by the Argo Biot and Eyring John relations, which gives fairly good results, whereas deviations are more pronounced in the theoretical results obtained from the Lorentz Lorenz and the Gladstone–Dale relations, see table (3.4.1).

Table (3.4.1)
The comparison between average deviations of the refractive index calculated by mixing rules equations.

Lorentz Lorenz Eq.	**Gladstone Dale Eq.**	**Eyring John Eq.**	**Argo Biot Equation**	**Newton Equation**	**Mixing Rule Eq.**
0.000463077	0.000463889	0.000463348	0.000463348	0.000464644	**Average Deviation**

The effect of temperature on the refractive index of all concentrations of olive/corn oil mixtures and olive/acetone solutions calculated by of Lorentz Lorenz equation, Gladstone Dale relation, Arago Biot equation, Newton equation and Eyring John equation could be accurately fitted by polynomial equation:

$$n = A_n + B_n T + C_n T^2 \cdots\cdots\cdots (3.4.6)$$

The fitting constants A_n, B_n, and C_n are given in tables (3.4.1-10) for all concentrations of olive/corn oil mixtures and olive/acetone solutions.

Table (3.4.2)

The fitting constants of the polynomial equation of refractive index versus temperature calculated using Lorentz Lorenz equation for all concentrations of olive/corn oil mixtures.

Percentage of Concentration	**A_n**	**B_n (K^{-1})**	**C_n (K^{-2})**	**MRE**
10% Olive Oil& 90% Corn Oil	1.53	-1.46×10^{-5}	-5.64×10^{-7}	0.001459
20% Olive Oil& 80% Corn Oil	1.56	-2.51×10^{-4}	-1.87×10^{-7}	0.002593
30% Olive Oil& 70% Corn Oil	1.56	-2.09×10^{-4}	-2.57×10^{-7}	0.001926
40% Olive Oil& 60% Corn Oil	1.55	-1.67×10^{-4}	-3.26×10^{-7}	0.000301
50% Olive Oil& 50% Corn Oil	1.54	-1.25×10^{-4}	-3.96×10^{-7}	0.002593
60% Olive Oil& 40% Corn Oil	1.54	-8.27×10^{-5}	-4.65×10^{-7}	0.002057
70% Olive Oil& 30% Corn Oil	1.53	-4.05×10^{-5}	-5.34×10^{-7}	0.00013
80% Olive Oil& 20% Corn Oil	1.52	1.59×10^{-6}	-6.03×10^{-7}	0.00234
90% Olive Oil& 10% Corn Oil	1.52	4.37×10^{-5}	-6.73×10^{-7}	0.002208

Table (3.4.3)

The fitting constants of the polynomial equation of refractive index versus temperature calculated using Gladstone Dale relation for all concentrations of olive/corn oil mixtures.

Percentage of Concentration	**A_n**	**B_n (K^{-1})**	**C_n (K^{-2})**	**MRE**
10% Olive Oil& 90% Corn Oil	1.53	-1.46×10^{-5}	-5.64×10^{-7}	0.001459
20% Olive Oil& 80% Corn Oil	1.56	-2.52×10^{-4}	-1.87×10^{-7}	0.002803
30% Olive Oil& 70% Corn Oil	1.56	-2.09×10^{-4}	-2.56×10^{-7}	0.00199
40% Olive Oil& 60% Corn Oil	1.55	-1.67×10^{-4}	-3.26×10^{-7}	0.000301
50% Olive Oil& 50% Corn Oil	1.54	-1.25×10^{-4}	-3.95×10^{-7}	0.002529
60% Olive Oil& 40% Corn Oil	1.54	-8.30×10^{-5}	-4.64×10^{-7}	0.002058
70% Olive Oil& 30% Corn Oil	1.53	-4.07×10^{-5}	-5.34×10^{-7}	0.000172
80% Olive Oil& 20% Corn Oil	1.52	1.39×10^{-6}	-6.03×10^{-7}	0.002382
90% Olive Oil& 10% Corn Oil	1.52	4.36×10^{-5}	-6.72×10^{-7}	0.002252

Table (3.4.4)

The fitting constants of the polynomial equation of refractive index versus temperature calculated using Arago Biot equation for all concentrations of olive/corn oil mixtures.

Percentage of Concentration	**A_n**	**B_n (K^{-1})**	**C_n (K^{-2})**	**MRE**
10% Olive Oil& 90% Corn Oil	1.49	2.27×10^{-4}	-9.51×10^{-7}	0.000119
20% Olive Oil& 80% Corn Oil	1.56	-2.52×10^{-4}	-1.87×10^{-7}	0.002803
30% Olive Oil& 70% Corn Oil	1.56	-2.09×10^{-4}	-2.56×10^{-7}	0.00199
40% Olive Oil& 60% Corn Oil	1.55	-1.67×10^{-4}	-3.26×10^{-7}	0.000301
50% Olive Oil& 50% Corn Oil	1.54	-1.25×10^{-4}	-3.95×10^{-7}	0.002529
60% Olive Oil& 40% Corn Oil	1.54	-8.30×10^{-5}	-4.64×10^{-7}	0.002058
70% Olive Oil& 30% Corn Oil	1.53	-4.07×10^{-5}	-5.34×10^{-7}	0.000172
80% Olive Oil& 20% Corn Oil	1.52	1.39×10^{-6}	-6.03×10^{-7}	0.002382
90% Olive Oil& 10% Corn Oil	1.52	4.36×10^{-5}	-6.72×10^{-7}	0.002252

Table (3.4.5)

The fitting constants of the polynomial equation of refractive index versus temperature calculated using Newton equation for all concentrations of olive/corn oil mixtures.

MRE	**C_n (K^{-2})**	**B_n (K^{-1})**	**A_n**	**Percentage of Concentration**
0.000148	-5.65×10^{-7}	-1.45×10^{-5}	1.53	10% Olive Oil& 90% Corn Oil
0.003814	-1.87×10^{-7}	-2.52×10^{-4}	1.56	20% Olive Oil& 80% Corn Oil
0.001095	-2.56×10^{-7}	-2.10×10^{-4}	1.56	30% Olive Oil& 70% Corn Oil
0.001562	-3.25×10^{-7}	-1.67×10^{-4}	1.55	40% Olive Oil& 60% Corn Oil
0.00253	-3.95×10^{-7}	-1.25×10^{-4}	1.54	50% Olive Oil& 50% Corn Oil
0.000236	-4.64×10^{-7}	-8.31×10^{-5}	1.54	60% Olive Oil& 40% Corn Oil
0.002728	-5.33×10^{-7}	-4.09×10^{-5}	1.53	70% Olive Oil& 30% Corn Oil
0.001388	-6.03×10^{-7}	1.31×10^{-6}	1.52	80% Olive Oil& 20% Corn Oil
0.003797	-6.72×10^{-7}	4.35×10^{-5}	1.52	90% Olive Oil& 10% Corn Oil

Table (3.4.6)

The fitting constants of the polynomial equation of refractive index versus temperature calculated using Eyring John equation for all concentrations of olive/corn oil mixtures.

MRE	**C_n (K^{-2})**	**B_n (K^{-1})**	**A_n**	**Percentage of Concentration**
0.00148	-6.73×10^{-7}	4.37×10^{-5}	1.52	10% Olive Oil& 90% Corn Oil
0.002803	-6.03×10^{-7}	1.53×10^{-6}	1.52	20% Olive Oil& 80% Corn Oil
0.001926	-5.34×10^{-7}	-4.05×10^{-5}	1.53	30% Olive Oil& 70% Corn Oil
0.000301	-4.65×10^{-7}	-8.28×10^{-5}	1.54	40% Olive Oil& 60% Corn Oil
0.002529	-3.95×10^{-7}	-1.25×10^{-4}	1.54	50% Olive Oil& 50% Corn Oil
0.002035	-3.26×10^{-7}	-1.67×10^{-4}	1.55	60% Olive Oil& 40% Corn Oil
0.00013	-5.34×10^{-7}	-4.05×10^{-5}	1.53	70% Olive Oil& 30% Corn Oil
0.002353	-6.03×10^{-7}	1.53×10^{-6}	1.52	80% Olive Oil& 20% Corn Oil
0.002208	-6.73×10^{-7}	4.37×10^{-5}	1.52	90% Olive Oil& 10% Corn Oil

Table (3.4.7)

The fitting constants of the polynomial equation of refractive index versus temperature calculated using Lorentz Lorenz equation for all concentrations of olive/acetone solutions.

MRE	C_n (K^{-2})	B_n (K^{-1})	A_n	**Percentage of Concentration**
0.001141435	-6.52×10^{-7}	1.16×10^{-5}	1.52	5% Acetone& 95% Olive Oil
0.002315924	-5.63×10^{-7}	-6.21×10^{-5}	1.53	10% Acetone& 90% Olive Oil
0.003253259	-4.74×10^{-7}	-1.35×10^{-4}	1.53	15% Acetone& 85% Olive Oil
0.002038818	-3.86×10^{-7}	-2.08×10^{-4}	1.54	25% Acetone& 75% Olive Oil
0.000683424	-2.99×10^{-7}	-2.80×10^{-4}	1.55	30% Acetone& 70% Olive Oil
0.002225313	-1.25×10^{-7}	-4.23×10^{-4}	1.57	35% Acetone& 65% Olive Oil
0.003341358	-3.91×10^{-8}	-4.94×10^{-4}	1.57	40% Acetone& 60% Olive Oil

Table (3.4.8)

The fitting constants of the polynomial equation of refractive index versus temperature calculated using Gladstone Dale relation for all concentrations of olive/acetone solutions.

MRE	C_n (K^{-2})	B_n (K^{-1})	A_n	Percentage of Concentration
0.001629512	-6.57×10^{-7}	1.62×10^{-5}	1.52	5% Acetone& 95% Olive Oil
0.003251675	-5.72×10^{-7}	-5.35×10^{-5}	1.53	10% Acetone& 90% Olive Oil
0.002039261	-4.88×10^{-7}	-1.23×10^{-4}	1.53	15% Acetone& 85% Olive Oil
0.000482857	-4.03×10^{-7}	-1.93×10^{-4}	1.54	25% Acetone& 75% Olive Oil
0.001085997	-3.18×10^{-7}	-2.63×10^{-4}	1.55	30% Acetone& 70% Olive Oil
0.002603102	-1.49×10^{-7}	-4.02×10^{-4}	1.56	35% Acetone& 65% Olive Oil
0.001043859	-6.43×10^{-8}	-4.72×10^{-4}	1.57	40% Acetone& 60% Olive Oil

Table (3.4.9)

The fitting constants of the polynomial equation of refractive index versus temperature calculated using Arago Biot equation for all concentrations of olive/acetone solutions.

MRE	C_n (K^{-2})	B_n (K^{-1})	A_n	Percentage of Concentration
0.001629512	-6.57×10^{-7}	1.62×10^{-5}	1.52	5% Acetone& 95% Olive Oil
0.003251675	-5.72×10^{-7}	-5.35×10^{-5}	1.53	10% Acetone& 90% Olive Oil
0.002039261	-4.88×10^{-7}	-1.23×10^{-4}	1.53	15% Acetone& 85% Olive Oil
0.000482857	-4.03×10^{-7}	-1.93×10^{-4}	1.54	25% Acetone& 75% Olive Oil
0.001085997	-3.18×10^{-7}	-2.63×10^{-4}	1.55	30% Acetone& 70% Olive Oil
0.002603102	-1.49×10^{-7}	-4.02×10^{-4}	1.56	35% Acetone& 65% Olive Oil
0.001043859	-6.43×10^{-8}	-4.72×10^{-4}	1.57	40% Acetone& 60% Olive Oil

Table (3.4.10)

The fitting constants of the polynomial equation of refractive index versus temperature calculated using Newton equation for all concentrations of olive/acetone solutions.

MRE	C_n (K^{-2})	B_n (K^{-1})	A_n	Percentage of Concentration
0.00196008	-6.70×10^{-7}	2.55×10^{-5}	1.52	5% Acetone& 95% Olive Oil
0.002944301	-5.83×10^{-7}	-4.47×10^{-5}	1.52	10% Acetone& 90% Olive Oil
0.000969759	-4.80×10^{-7}	-1.24×10^{-4}	1.53	15% Acetone& 85% Olive Oil
0.000928256	-4.12×10^{-7}	-1.83×10^{-4}	1.54	25% Acetone& 75% Olive Oil
0.002641968	-3.28×10^{-7}	-2.51×10^{-4}	1.55	30% Acetone& 70% Olive Oil
0.000719048	-1.57×10^{-7}	-3.90×10^{-4}	1.56	35% Acetone& 65% Olive Oil
0.001182837	-9.84×10^{-8}	-4.44×10^{-4}	1.57	40% Acetone& 60% Olive Oil

Table (3.4.11)

The fitting constants of the polynomial equation of refractive index versus temperature calculated using Eyring John equation for all concentrations of olive/acetone solutions.

MRE	C_n (K^{-2})	B_n (K^{-1})	A_n	Percentage of Concentration
0.001414183	-6.55×10^{-7}	1.42×10^{-5}	1.52	5% Acetone& 95% Olive Oil
0.002788444	-5.69×10^{-7}	-5.73×10^{-5}	1.53	10% Acetone& 90% Olive Oil
0.002568466	-4.83×10^{-7}	-1.28×10^{-4}	1.53	15% Acetone& 85% Olive Oil
0.001108682	-3.97×10^{-7}	-1.99×10^{-4}	1.54	25% Acetone& 75% Olive Oil
0.000354758	-3.11×10^{-7}	-2.70×10^{-4}	1.55	30% Acetone& 70% Olive Oil
0.003442167	-1.40×10^{-7}	-4.11×10^{-4}	1.57	35% Acetone& 65% Olive Oil
0.001971364	-5.49×10^{-8}	-4.81×10^{-4}	1.57	40% Acetone& 60% Olive Oil

From Maxwell's electromagnetic theory, and the wave theory of light, it was found that the specific refraction is a constant quantity for a substance with refractive index n and density ρ. The specific refraction is fairly constant and independent of temperature. Moreover, the specific refraction R_D is applicable to any phase of the substance. Specific refraction has a several mathematical forms and it can be calculated from many mixing rule equations.

1- The specific refraction R_D calculated from Lorentz Lorenz equation (Deosarkar *et al.*, 2013; Vuksanovic *et al.*, 2014):

$$R_D = \frac{(n_D^2 - 1)}{(n_D^2 + 2)} \times \frac{1}{\rho} \cdots\cdots\cdots (3.4.7)$$

2- The specific refraction R_D calculated from Gladstone Dale relation (Young and Finn, 1940; Vuksanovic *et al.*, 2014):

$$R_D = (n_D - 1) \times \frac{1}{\rho} \cdots\cdots\cdots (3.4.8)$$

3- The specific refraction R_D calculated from Eykman relation (Young and Finn, 1940; Vuksanovic *et al.*, 2014):

$$R_D = \frac{(n_D^2 - 1)}{(n_D + 0.4)} \times \frac{1}{\rho} \cdots\cdots\cdots (3.4.9)$$

4- The specific refraction R_D calculated from Newton equation (Young and Finn, 1940; Vuksanovic *et al.*, 2014):

$$R_D = (n_D^2 - 1) \times \frac{1}{\rho} \cdots\cdots\cdots (3.4.10)$$

5- The specific refraction R_D calculated from Oster relation (Vuksanovic *et al.*, 2014):

$$R_D = \frac{(n_D^2 - 1)(2n_D^2 + 1)}{n_D^2} \times \frac{1}{\rho} \cdots\cdots\cdots (3.4.11)$$

6- The specific refraction R_D calculated from Arago Biot equation (Vuksanovic *et al.*, 2014):

$$R_D = n_D \times \frac{1}{\rho} \cdots\cdots\cdots (3.4.12)$$

The value of specific of refraction calculated by Lorentz Lorenz mixing rule equation is directly proportional dependent on electric

polarizability and on thermal expansion (Khodier, 2002). The specific refractivity reflects the changes in the properties of the ions due to polarization or deformation of their electron shells under the influence of the electric field of neighboring ions. The specific of refraction of any liquid organic substance is the sum of the specific of refractions of its individual components (Lee *et al.*, 2005). Figures (3.4.11-21) shows the specific refraction for some concentrations of olive/corn oil mixtures and olive/acetone solutions using Lorentz Lorenz equation, Gladstone Dale relation, Eykman relation, Newton equation, Oster relation and Arago Biot equation. The effect of temperature on the specific refraction of some concentrations of olive/corn oil mixtures and olive/acetone solutions calculated by Lorentz Lorenz equation, Gladstone Dale relation, Eykman relation, Newton equation, Oster relation and Arago Biot equation could be accurately fitted by polynomial equation:

$$R_D = A_R + B_R T + C_R T^2 \cdots\cdots\cdots (3.4.13)$$

The fitting constants A_R, B_R, and C_R are given in tables (3.4.11-21) for some concentrations of olive/corn oil mixtures and olive/acetone solutions.

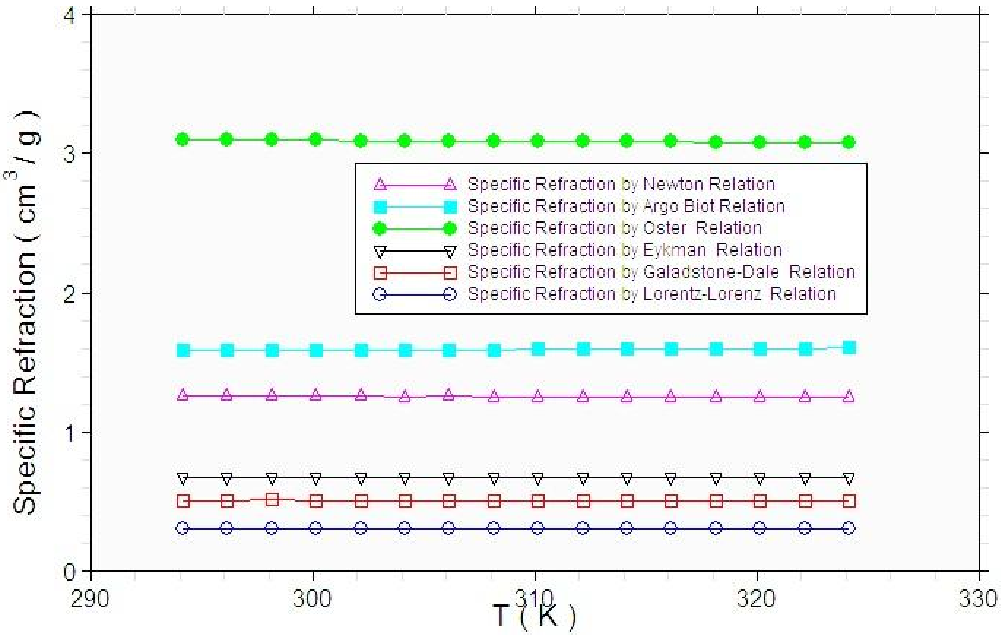


Figure (3.4.11)
Specific refraction versus temperature of 100% corn oil and 0% olive oil mixture using different mixing rule equations.

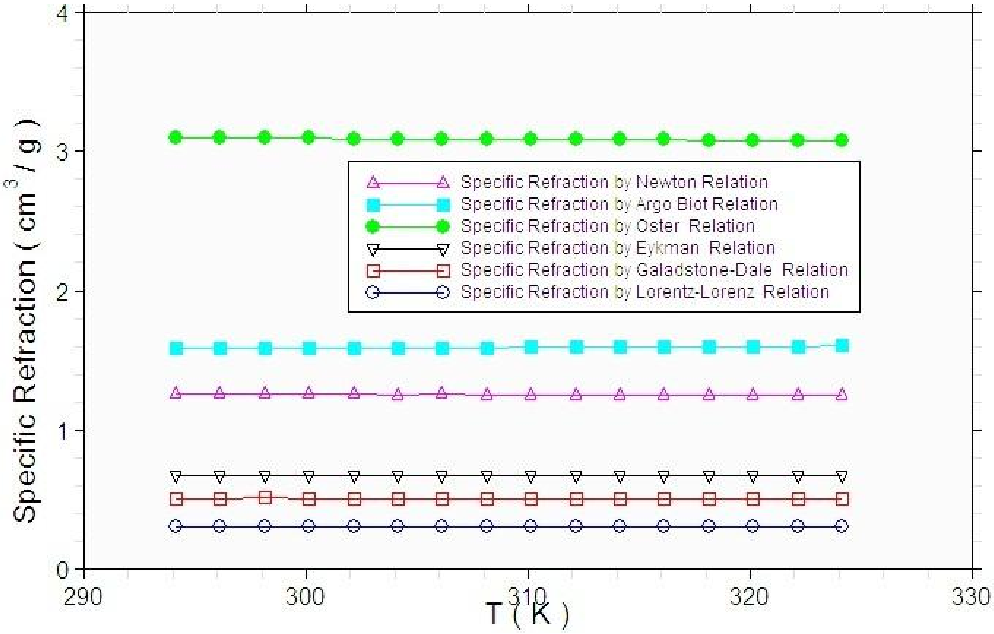


Figure (3.4.12)
Specific refraction versus temperature of 80% corn oil and 20% olive oil mixture using different mixing rule equations.

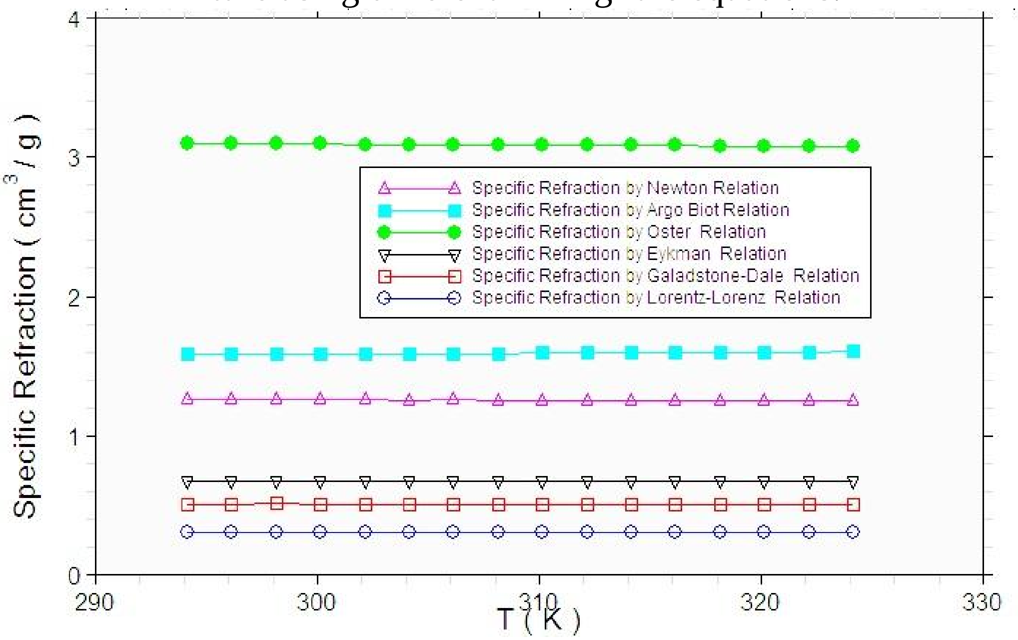


Figure (3.4.13)
Specific refraction versus temperature of 60% corn oil and 40% olive oil mixture using different mixing rule equations.

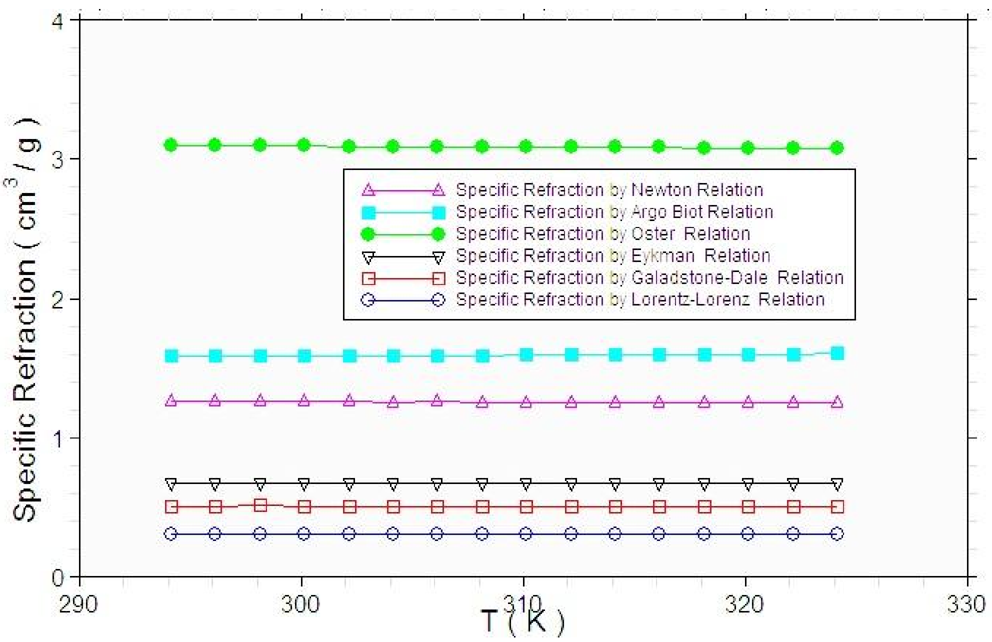


Figure (3.4.14)
Specific refraction versus temperature of 40% corn oil and 60% olive oil mixture using different mixing rule equations.

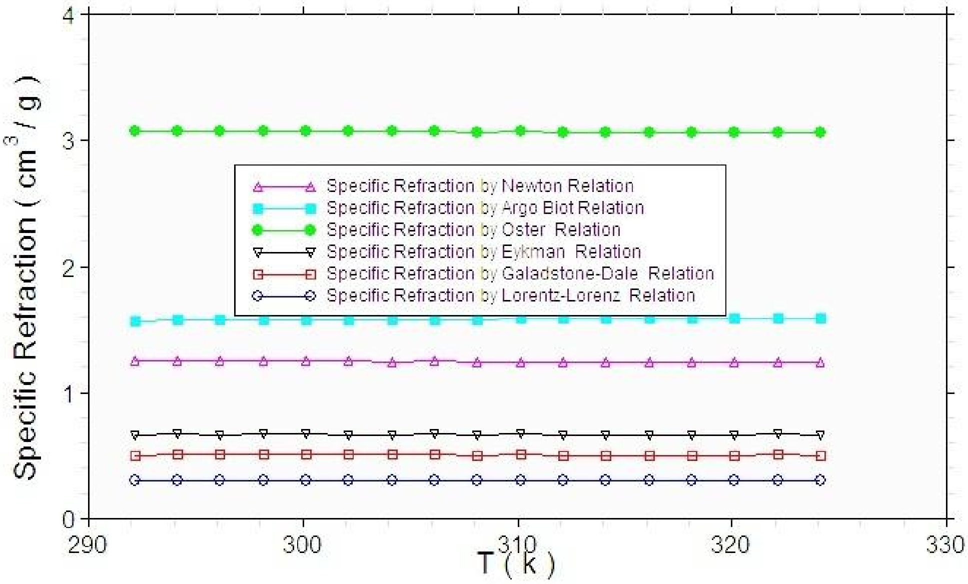


Figure (3.4.15)
Specific refraction versus temperature of 20% corn oil and 80% olive oil mixture using different mixing rule equations.

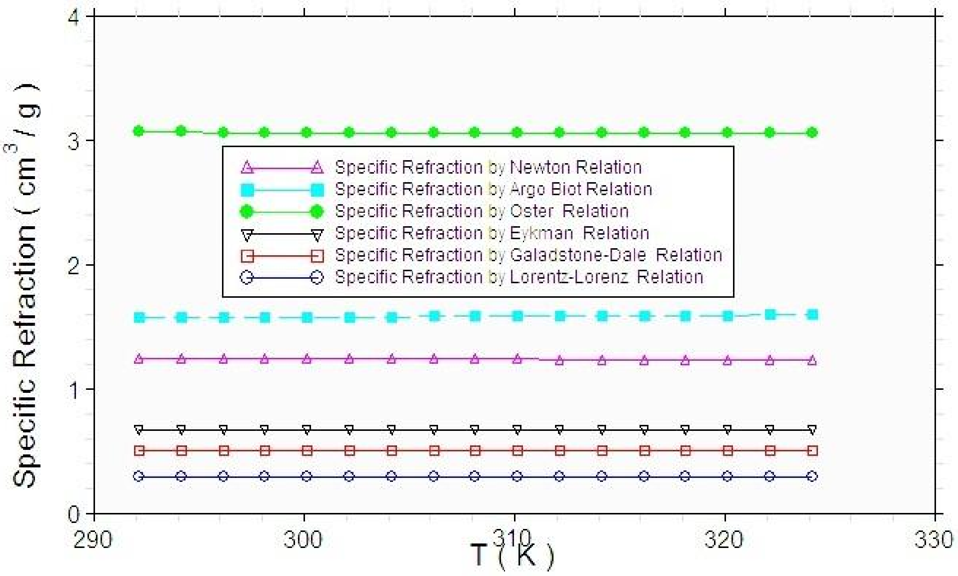


Figure (3.4.16)
Specific refraction versus temperature of 0% corn oil and 100% olive oil mixture using different mixing rule equations.

The specific of refraction is one of the hallmarks of substance and that because of its independent on temperature. According to the information available, there is no theoretical relation between the specific of refraction expressions, but all of them are independent on temperature. It can be clearly observed from figures (3.4.11-16) that the specific of refraction for each concentration and for all theoretical models of mixing rules is independent on temperature. From all previous figures we can notice that Oster has the highest specific of refraction and Lorentz Lorenz has the lowest. Also it can be observed that the change in concentration caused a slightly change in specific of refraction for all theoretical models of mixing rules that because of the strong convergence in composition between both oils. The slightly changes of the specific of refraction of Lorentz Lorenz mixing rule equation may be caused by the small changes in electrical polarizability or by small changes in thermal expansion of oil mixtures. Sometimes these small changes in specific of refraction can be explained by the chemical weakness of vegetable oils. And this chemical weakness makes the oils suitable for use in food.

Table (3.4.12)
The fitting constants of the polynomial equation of specific refraction versus temperature of 100% corn oil and 0% olive oil mixture calculated using different mixing rule equations.

MRE	**C_R ($cm^3/g.K^2$)**	**B_R ($cm^3/g.K$)**	**A_R (cm^3/g)**	**The used mixing rule equation for calculation of specific refraction**
0.001338	4.47×10^{-7}	-2.66×10^{-4}	0.339	Lorentz Lorenz
0.000478	7.50×10^{-7}	-5.01×10^{-4}	0.588	Gladstone Dale
0.000317	1.00×10^{-6}	-6.36×10^{-4}	0.768	Eykman
0.001905	4.61×10^{-6}	-0.00325	3.63	Oster
0.000668	3.05×10^{-6}	-0.00116	1.65	Arago Biot
0.002406	1.84×10^{-6}	-0.00141	1.51	Newton

Table (3.4.13)
The fitting constants of the polynomial equation of specific refraction versus temperature of 80% corn oil and 20% olive oil mixture calculated using different mixing rule equations.

MRE	**C_R ($cm^3/g.K^2$)**	**B_R ($cm^3/g.K$)**	**A_R (cm^3/g)**	**The used mixing rule equation for calculation of specific refraction**
0.00131	-3.78×10^{-7}	2.47×10^{-4}	0.259	Lorentz Lorenz
0.000621	-8.41×10^{-7}	4.87×10^{-4}	0.434	Gladstone Dale
5.63×10^{-5}	-9.87×10^{-7}	5.98×10^{-4}	0.576	Eykman
0.000239	-5.67×10^{-6}	0.00314	2.64	Oster
0.001666	1.12×10^{-6}	5.58E-05	1.46	Arago Biot
0.00311	-2.76×10^{-6}	0.00144	1.06	Newton

Table (3.4.14)
The fitting constants of the polynomial equation of specific refraction versus temperature of 60% corn oil and 40% olive oil mixture calculated using different mixing rule equations.

MRE	**C_R ($cm^3/g.K^2$)**	**B_R ($cm^3/g.K$)**	**A_R (cm^3/g)**	**The used mixing rule equation for calculation of specific refraction**
0.002458	-1.34×10^{-6}	8.55×10^{-4}	0.165	Lorentz Lorenz
0.000564	-2.55×10^{-6}	0.00156	0.267	Gladstone Dale
2.64×10^{-6}	-3.20×10^{-6}	0.00199	0.359	Eykman
0.001327	-1.63×10^{-5}	0.0098	1.6	Oster
0.000178	-3.01×10^{-6}	0.00267	1.05	Arago Biot
0.000595	-7.23×10^{-6}	0.00425	0.626	Newton

Table (3.4.15)

The fitting constants of the polynomial equation of specific refraction versus temperature of 40% corn oil and 60% olive oil mixture calculated using different mixing rule equations.

MRE	C_R ($cm^3/g.K^2$)	B_R ($cm^3/g.K$)	A_R (cm^3/g)	The used mixing rule equation for calculation of specific refraction
0.00047	5.81×10^{-7}	-3.43×10^{-4}	0.351	Lorentz Lorenz
0.000482	8.22×10^{-7}	-5.35×10^{-4}	0.592	Gladstone Dale
0.000501	1.18×10^{-6}	-7.35×10^{-4}	0.782	Eykman
0.000331	4.59×10^{-6}	-0.00316	3.61	Oster
0.001046	5.60×10^{-6}	-0.00271	1.89	Arago Biot
0.00239	1.51×10^{-6}	-0.00118	1.47	Newton

Table (3.4.16)

The fitting constants of the polynomial equation of specific refraction versus temperature of 20% corn oil and 80% olive oil mixture calculated using different mixing rule equations.

MRE	C_R ($cm^3/g.K^2$)	B_R ($cm^3/g.K$)	A_R (cm^3/g)	The used mixing rule equation for calculation of specific refraction
0.001767	-3.85×10^{-7}	2.62×10^{-4}	0.255	Lorentz Lorenz
0.000512	-6.89×10^{-7}	4.11×10^{-4}	0.441	Gladstone Dale
0.000512	-8.80×10^{-7}	5.55×10^{-4}	0.577	Eykman
0.000647	-4.25×10^{-6}	0.00237	2.73	Oster
0.001969	-8.64×10^{-7}	0.00133	1.25	Arago Biot
0.000749	-1.84×10^{-6}	9.18×10^{-4}	1.13	Newton

Table (3.4.17)

The fitting constants of the polynomial equation of specific refraction versus temperature of 0% corn oil and 100% olive oil mixture calculated using different mixing rule equations.

MRE	C_R ($cm^3/g.K^2$)	B_R ($cm^3/g.K$)	A_R (cm^3/g)	The used mixing rule equation for calculation of specific refraction
0.001159	-3.83×10^{-7}	2.51×10^{-4}	0.258	Lorentz Lorenz
0.000245	-7.51×10^{-7}	4.31×10^{-4}	0.442	Gladstone Dale
0.000394	-9.24×10^{-7}	5.60×10^{-4}	0.581	Eykman
0.001583	-4.82×10^{-6}	0.00261	2.72	Oster
0.001097	-1.52×10^{-8}	7.71×10^{-4}	1.35	Arago Biot
0.002268	-2.21×10^{-6}	0.0011	1.11	Newton

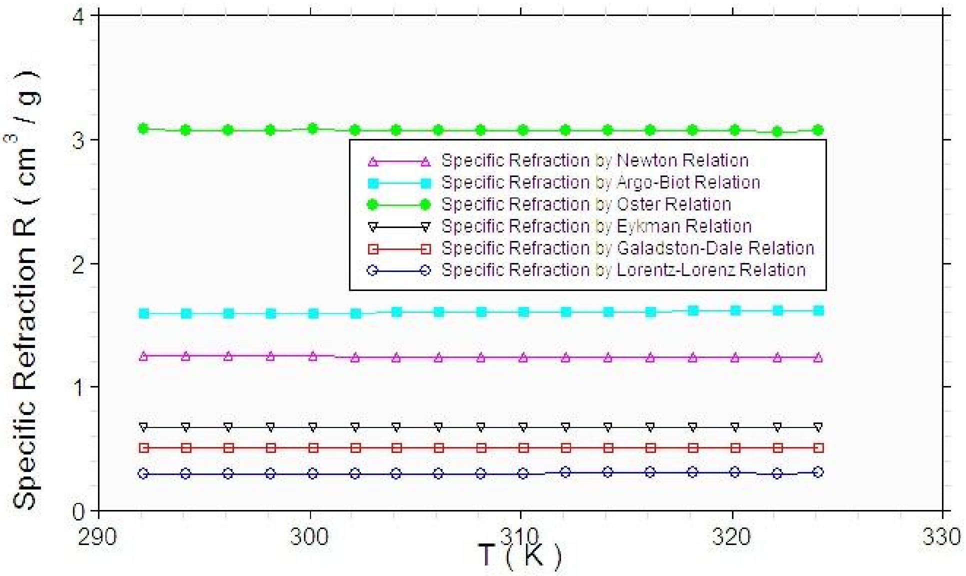


Figure (3.4.17)
Specific refraction versus temperature of 5% acetone and 95% olive oil solution using different mixing rule equations.

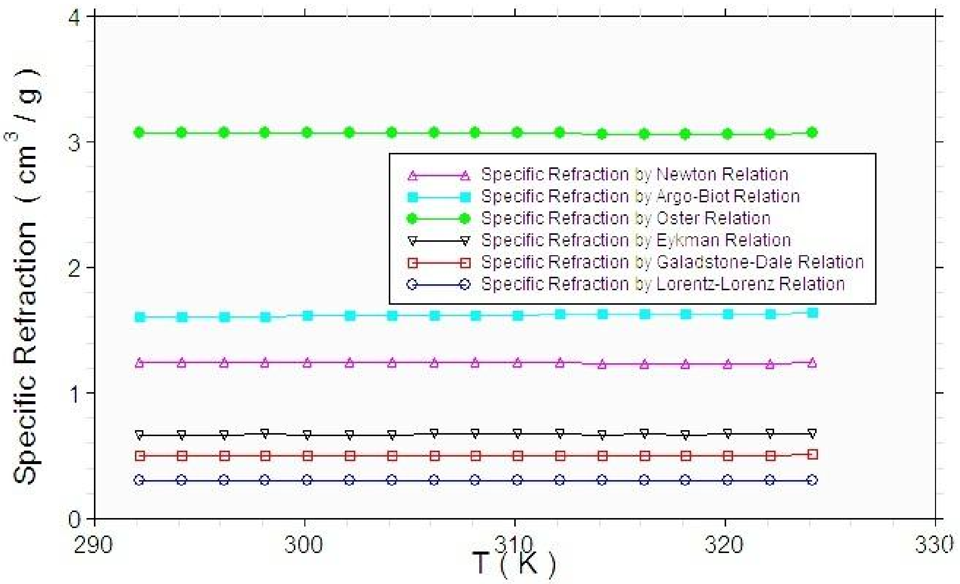


Figure (3.4.18)
Specific refraction versus temperature of 15% acetone and 85% olive oil solution using different mixing rule equations.

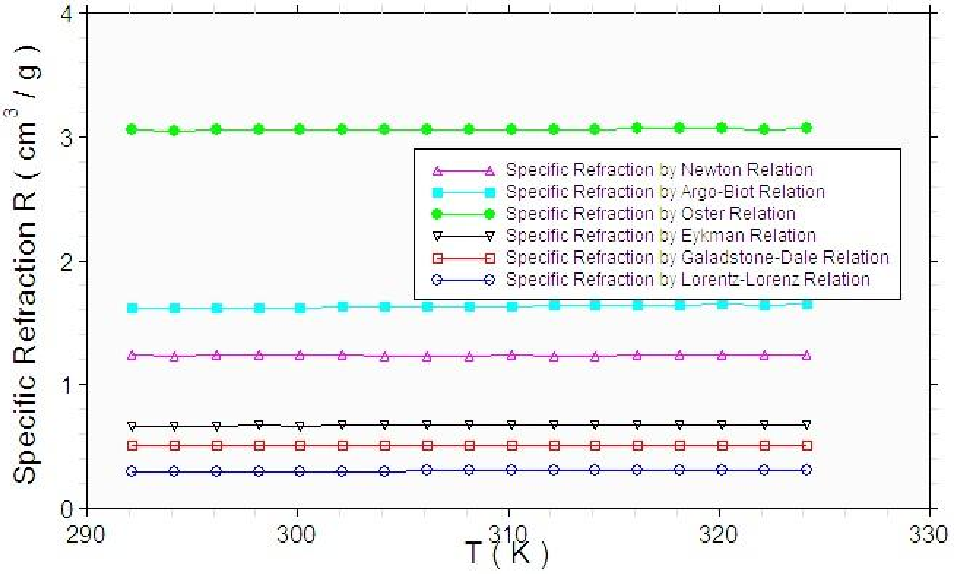


Figure (3.4.19)
Specific refraction versus temperature of 25% acetone and 75% olive oil solution using different mixing rule equations.

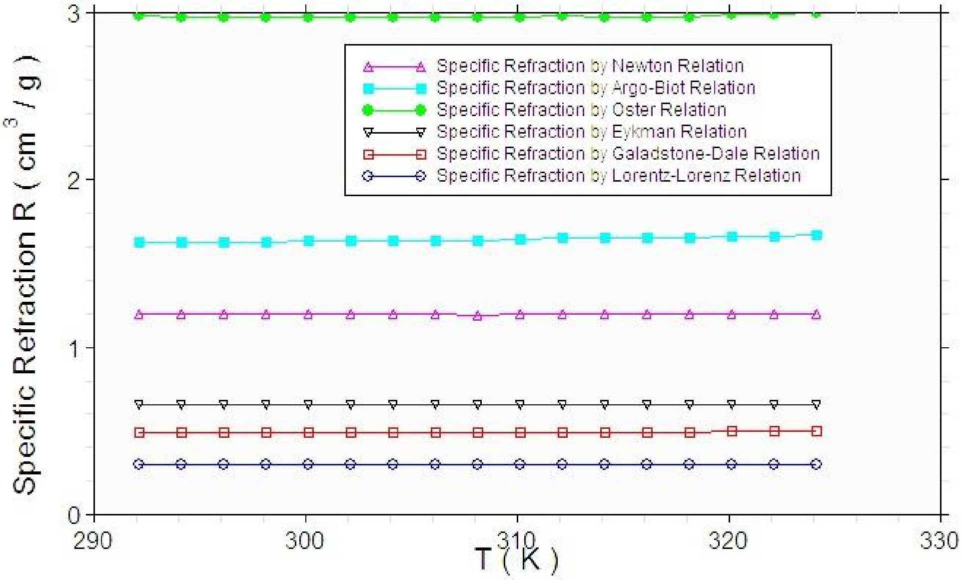


Figure (3.4.20)
Specific refraction versus temperature of 35% acetone and 65% olive oil solution using different mixing rule equations.

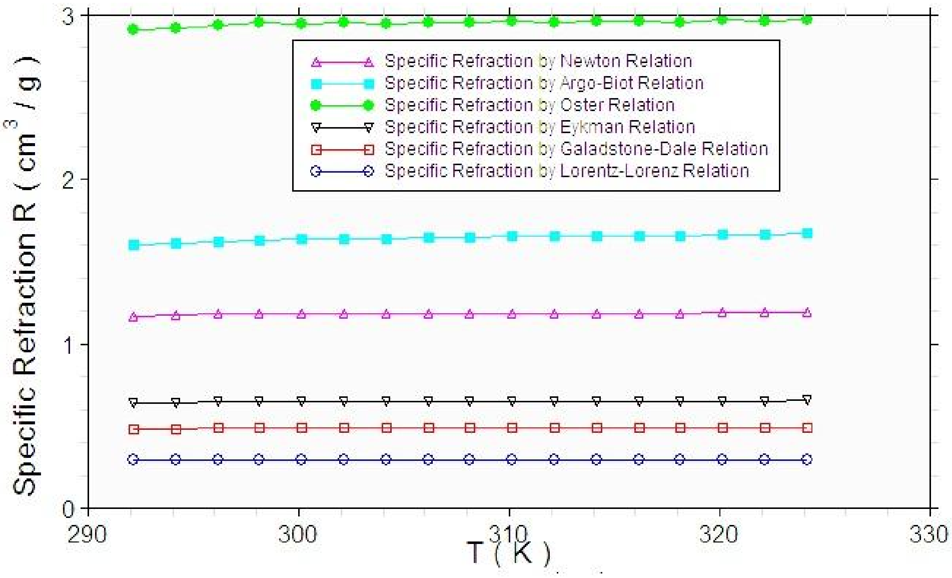


Figure (3.4.21)
Specific refraction versus temperature of 40% acetone and 60% olive oil solution using different mixing rule equations.

Table (3.4.18)
The fitting constants of the polynomial equation of specific refraction versus temperature of 5% acetone and 95% olive oil solution calculated using different mixing rule equations.

MRE	C_R ($cm^3/g.K^2$)	B_R ($cm^3/g.K$)	A_R (cm^3/g)	The used mixing rule equation for calculation of specific refraction
0.000987297	-3.24×10^{-7}	2.17×10^{-4}	0.265	Lorentz Lorenz
0.000450662	-6.18×10^{-7}	3.53×10^{-4}	0.455	Gladstone Dale
0.000322243	-7.66×10^{-7}	4.68×10^{-4}	0.597	Eykman
0.001705605	-3.90×10^{-6}	0.00206	2.8	Oster
0.001113487	3.61×10^{-8}	8.01×10^{-4}	1.35	Arago Biot
0.00312442	-1.78×10^{-6}	8.32×10^{-4}	1.16	Newton

Table (3.4.19)
The fitting constants of the polynomial equation of specific refraction versus temperature of 15% acetone and 85% olive oil solution calculated using different mixing rule equations.

MRE	C_R ($cm^3/g.K^2$)	B_R ($cm^3/g.K$)	A_R (cm^3/g)	The used mixing rule equation for calculation of specific refraction
0.000951804	1.33×10^{-6}	-7.78×10^{-4}	0.415	Lorentz Lorenz
0.002721715	2.46×10^{-6}	-0.0015	0.735	Gladstone Dale
0.00063829	3.13×10^{-6}	-0.00188	0.951	Eykman
0.002482941	1.56×10^{-5}	-0.00975	4.58	Oster
0.000924234	4.96×10^{-6}	-0.00208	1.79	Arago Biot
0.003508954	6.78×10^{-6}	-0.00435	1.94	Newton

Table (3.4.20)

The fitting constants of the polynomial equation of specific refraction versus temperature of 25% acetone and 75% olive oil solution calculated using different mixing rule equations.

MRE	C_R (cm^3/g.K^2)	B_R (cm^3/g.K)	A_R (cm^3/g)	The used mixing rule equation for calculation of specific refraction
0.001814896	5.52×10^{-6}	-0.00334	1.74	Lorentz Lorenz
0.003348818	5.68×10^{-6}	-0.00233	1.81	Gladstone Dale
0.001196283	1.32×10^{-5}	-0.00768	4.17	Eykman
0.000594067	2.73×10^{-6}	-0.00153	0.879	Oster
0.000462253	2.11×10^{-6}	-0.0012	0.675	Arago Biot
0.001466229	5.52×10^{-6}	-0.00334	1.74	Newton

Table (3.4.21)

The fitting constants of the polynomial equation of specific refraction versus temperature of 35% acetone and 65% olive oil solution calculated using different mixing rule equations.

MRE	C_R (cm^3/g.K^2)	B_R (cm^3/g.K)	A_R (cm^3/g)	The used mixing rule equation for calculation of specific refraction
0.001022847	5.01×10^{-6}	-0.00299	0.741	Lorentz Lorenz
0.00546231	8.92×10^{-6}	-0.00538	1.3	Gladstone Dale
0.003761459	1.15×10^{-5}	-0.0069	1.69	Eykman
0.003643866	5.56×10^{-5}	-0.0337	8.09	Oster
0.005518174	2.00×10^{-5}	-0.0109	3.11	Arago Biot
0.009526504	2.36×10^{-5}	-0.0145	3.41	Newton

Table (3.4.22)

The fitting constants of the polynomial equation of specific refraction versus temperature of 40% acetone and 60% olive oil solution calculated using different mixing rule equations.

MRE	**C_R** (cm3/g.K2)	**B_R** (cm3/g.K)	**A_R** (cm3/g)	**The used mixing rule equation for calculation of specific refraction**
0.002349323	-4.72×10^{-6}	0.00309	-0.21	Lorentz Lorenz
0.00045387	-7.51×10^{-6}	0.00488	-0.301	Gladstone Dale
0.001539851	-1.02×10^{-5}	0.00664	-0.428	Eykman
0.003168422	-4.44×10^{-5}	0.0287	-1.68	Oster
0.009990671	-3.07×10^{-5}	0.0208	-1.83	Arago Biot
0.009518895	-1.71×10^{-5}	0.011	-0.569	Newton

3.5. The Thermal Modeling of dynamic Viscosity of Olive/Corn Oils and Olive/Acetone Mixtures Using Vogel and Andrade Empirical Equations.

Modeling the temperature effect on the dynamic viscosity of vegetable oils is important and has been investigated by various researchers (Stanciu, 2012; Nierat *et al.*, 2014; Neelamegam and Krishnaraj, 2011).

Two and three constant parameters formulas have been proposed for the representation of liquid viscosity as a function of temperature. The simplest two parameters formula to represent the liquid dynamic viscosity as a function of temperature was proposed by Andrade (AE) (Neelamegam and Krishnaraj, 2011; Stanciu, 2012), which is:

$$\eta = exp\left(A + \frac{B}{T}\right) \quad or \quad ln\eta = A + \frac{B}{T} \cdots\cdots\cdots (3.5.1)$$

And the three parameters formula of dynamic viscosity as a function of temperature was proposed by Vogel (VE) (Knezevic and Savic, 2006; Stanciu, 2012):

$$\eta = exp\left(A + \frac{B}{T + C}\right) \quad or \quad ln\eta = A + \frac{B}{T + C} \cdots\cdots\cdots (3.5.2)$$

Tables (3.5.1-4) show the values of the parameters of the theoretical models described by equations (3.5.1) and (3.5.2) and the mean relative error. Figures (3.5.1) and (3.5.2) illustrates the calculated values of dynamic viscosity versus temperature for all concentrations of olive/corn oil mixtures and olive/acetone solutions using Andrade and Vogel modeling equations.

Table (3.5.1)

The parameters of dynamic viscosity and the mean relative error of all concentrations of olive/corn oil mixtures of Andrade modeling equation.

MRE	**C (mPa.s/K^2)**	**B (mPa.s/K)**	**A (mPs.s)**	**Percentage of Concentration**
0.331816	3289	-19.7	0.0298	**100% Corn Oil & 0% Olive Oil**
0.148155	2758	-16.3	0.0243	**90% Corn Oil & 10% Olive Oil**
0.29229	3552	-21.4	0.0323	**80% Corn Oil & 20% Olive Oil**
0.048065	3674	-22.1	0.0334	**70% Corn Oil & 30% Olive Oil**
0.044248	3856	-23.2	0.0351	**60% Corn Oil & 40% Olive Oil**
0.155845	3659	-22	0.0332	**50% Corn Oil & 50% Olive Oil**
0.298361	3134	-18.7	0.0282	**40% Corn Oil & 60% Olive Oil**
0.094265	4615	-27.9	0.0424	**30% Corn Oil & 70% Olive Oil**
0.360334	4049	-24.4	0.0368	**20% Corn Oil & 80% Olive Oil**
0.283762	4057	-24.4	0.037	**10% Corn Oil & 90% Olive Oil**
0.364123	4260	-25.7	0.0388	**0% Corn Oil & 100% Olive Oil**

Table (3.5.2)

The parameters of dynamic viscosity and the mean relative error of all concentrations of olive/corn oil mixtures of Vogel modeling equation.

MRE	**C (mPa.s/K^2)**	**B (mPa.s/K)**	**A (mPs.s)**	**Percentage of Concentration**
0.042992	0.0318	-21	3485	**100% Corn Oil & 0% Olive Oil**
0.010856	0.027	-18	3019	**90% Corn Oil & 10% Olive Oil**
0.458882	0.0327	-21.7	3600	**80% Corn Oil & 20% Olive Oil**
0.400745	0.0359	-23.7	3915	**70% Corn Oil & 30% Olive Oil**
0.317548	0.0392	-25.7	4248	**60% Corn Oil & 40% Olive Oil**
0.379611	0.0315	-21	3503	**50% Corn Oil & 50% Olive Oil**
0.164453	0.0278	-18.5	3105	**40% Corn Oil & 60% Olive Oil**
0.308473	0.0368	-24.5	4082	**30% Corn Oil & 70% Olive Oil**
0.259782	0.0409	-26.9	4434	**20% Corn Oil & 80% Olive Oil**
0.032615	0.0416	-27.3	4500	**10% Corn Oil & 90% Olive Oil**
0.140914	0.0399	-26.3	4363	**0% Corn Oil & 100% Olive Oil**

Table (3.5.3)

The parameters of dynamic viscosity and the mean relative error of all concentrations of olive/acetone solutions of Andrade modeling equation.

MRE	C (mPa.s/K^2)	B (mPa.s/K)	A (mPs.s)	Percentage of Concentration
0	0.0216	-14.2	2355	5% Acetone& 95% Olive Oil
0.334231075	0.0113	-7.51	1264	10% Acetone& 90% Olive Oil
0.154681167	0.00515	-3.48	592	15% Acetone& 85% Olive Oil
0.081424315	0.00205	-1.4	243	25% Acetone& 75% Olive Oil
0.305355623	0.00153	-1.04	181	30% Acetone& 70% Olive Oil
0.059693433	9.93×10^{-4}	-0.685	120	35% Acetone& 65% Olive Oil
0.005018772	6.57×10^{-4}	-0.458	81.6	40% Acetone& 60% Olive Oil

Table (3.5.4)

The parameters of dynamic viscosity and the mean relative error of all concentrations of olive/acetone solutions of Vogel modeling equation.

MRE	**C (mPa.s/K^2)**	**B (mPa.s/K)**	**A (mPs.s)**	**Percentage of Concentration**
0.256258	0.0216	-14.2	2355	**5% Acetone& 95% Olive Oil**
0.102772	0.0112	-7.47	1257	**10% Acetone& 90% Olive Oil**
0.038912	0.00644	-4.27	714	**15% Acetone& 85% Olive Oil**
0.238187	0.00246	-1.65	282	**25% Acetone& 75% Olive Oil**
0.027415	0.00178	-1.2	205	**30% Acetone& 70% Olive Oil**
0.197293	0.00116	-0.79	136	**35% Acetone& 65% Olive Oil**
0.003652	2.86×10^{-4}	-0.229	46.3	**40% Acetone& 60% Olive Oil**

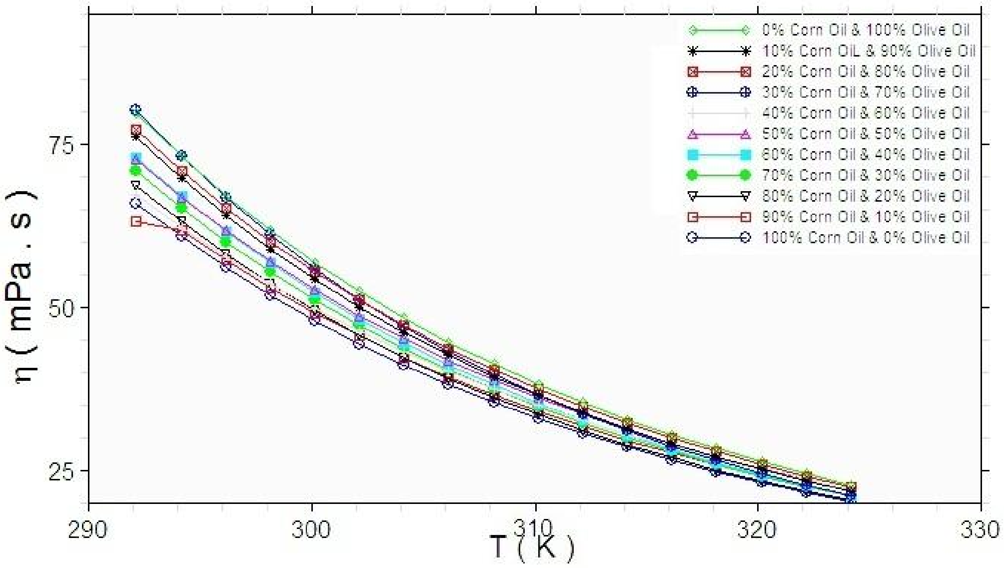


Figure (3.5.1)
The dynamical viscosity calculated by Andrade equation for all concentrations of olive/corn oil mixtures.

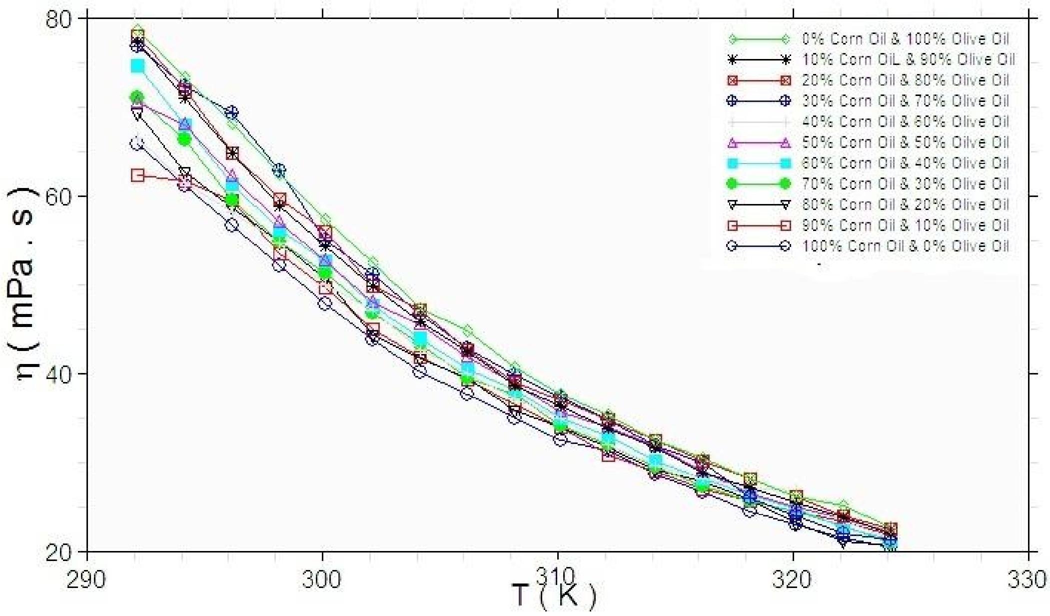


Figure (3.5.2)
The dynamical viscosity calculated by Vogel equation for all concentrations of olive/corn oil mixtures.

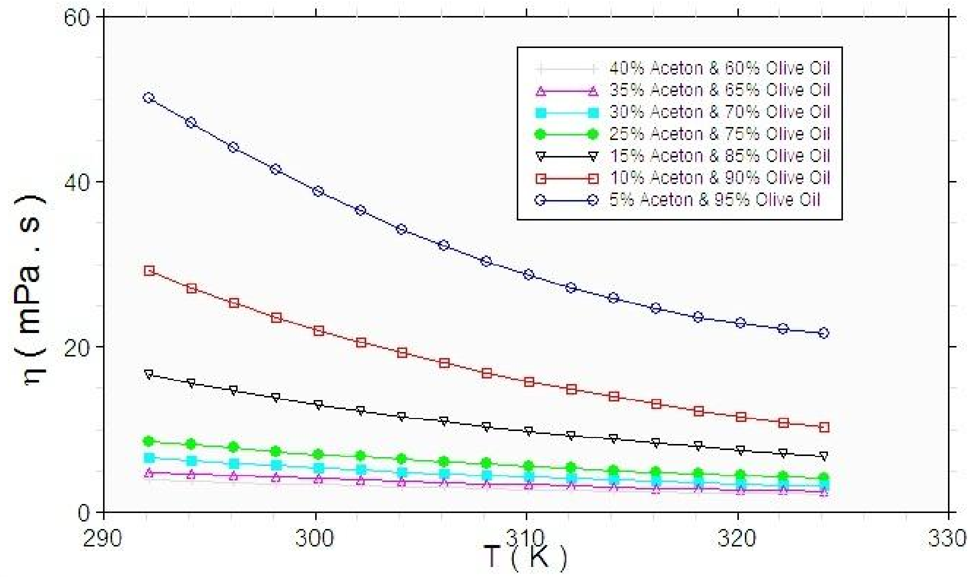


Figure (3.5.3)
The dynamical viscosity calculated by Andrade equation for all concentrations of olive/acetone solutions.

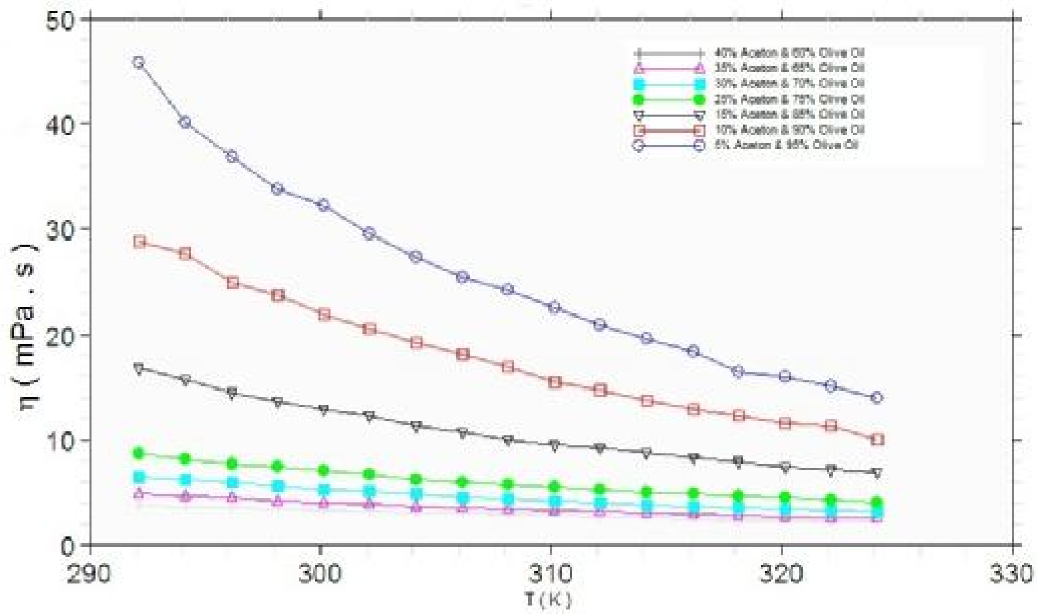


Figure (3.5.4)
The dynamical viscosity calculated by Vogel equation for all concentrations of olive/acetone solutions.

From the mean relative error in tables (3.5.1-4) we can see that the empirical relation which gives the best prediction in the present study for the temperature dependence of dynamic viscosity is described by Vogel equation.

3.6. The Comparison between Optical and Volumetric Determination of Thermal Expansion for all Concentrations of Olive/Corn Oil Mixtures and Olive/Acetone Solutions.

Coefficient of volumetric expansion γ_V measured the tendency of matter to change in volume in response to a change in temperature, through heat transfer. When a substance is heated, its particles begin moving more and thus usually maintain a greater average separation. In the general case of a gas, liquid, or solid, the volumetric coefficient of thermal expansion is given by (Serway and Jewelt, 2004).

$$\gamma_V = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P \text{ .... } (3.6.1)$$

The subscript P indicates that the pressure is held constant during the expansion, and the subscript V stresses that it is the volumetric (not linear) expansion that enters this general definition.

The volumetric coefficient of thermal expansion of vegetable oils is important and has been investigated by various researchers (Klofutar *et al.*, 1997). Figures (3.6.1) and (3.6.2) shows the coefficients of thermal expansion for all concentrations of olive/corn oil mixtures and olive/acetone solutions measured experimentally using volumetric method. The effect of temperature on the volumetric coefficient of thermal expansion could be accurately fitted by polynomial equation:

$$\gamma_V = A_\gamma + B_\gamma T + C_\gamma T^2 \text{ .... } (3.6.2)$$

The fitting constants A_γ, B_γ, and C_γ are given in tables (3.6.1) and (3.6.2) for all concentrations of olive/corn oil mixtures and olive/acetone solutions.

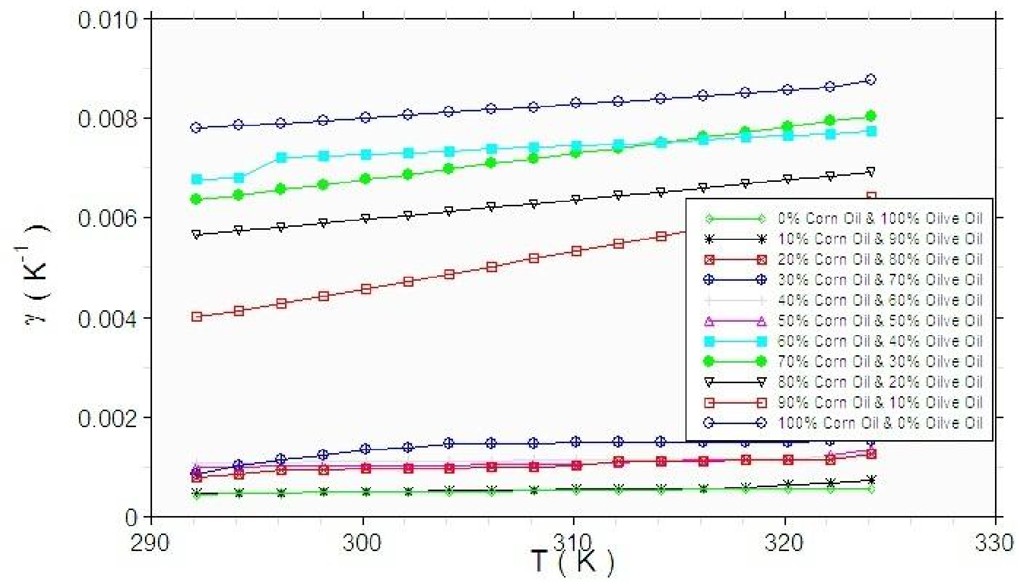


Figure (3.6.1)
The experimental coefficients of volumetric expansion versus temperature for all concentrations of olive/corn oil mixtures.

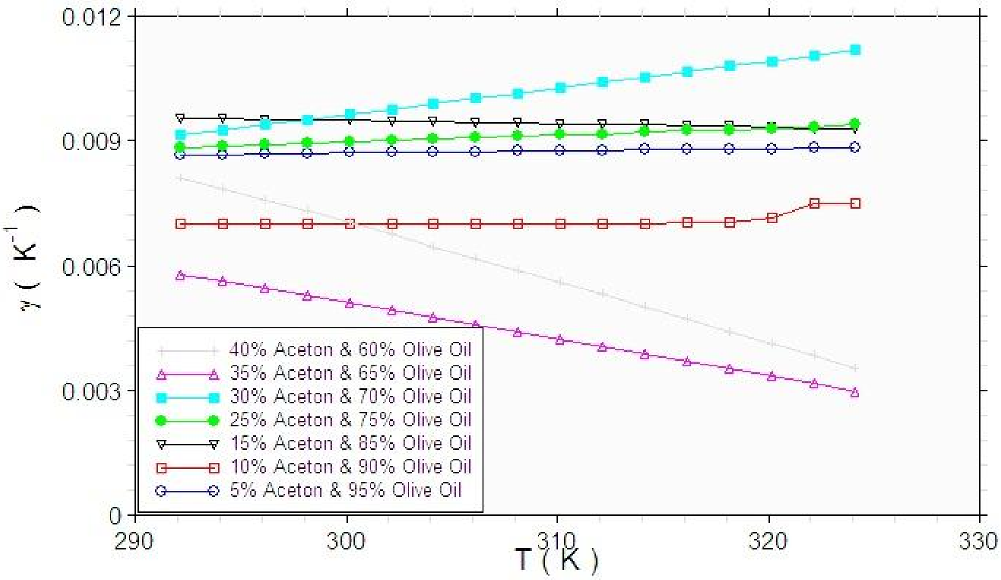


Figure (3.6.2)
The experimental coefficients of volumetric expansion versus temperature for all concentrations of olive/acetone solutions.

Table (3.6.1)
The fitting constants of the polynomial equation of the experimental coefficient of volumetric expansion versus temperature for all concentrations of olive/corn oil mixtures.

MRE	C_γ (K^{-3})	B_γ (K^{-2})	A_γ (K^{-1})	**Percentage of Concentration**
0.003417	1.39×10^{-7}	-5.76×10^{-5}	0.0128	100% Corn Oil & 0% Olive Oil
0.003351	1.43×10^{-7}	-1.19×10^{-5}	-0.00472	90% Corn Oil & 10% Olive Oil
1.45×10^{-5}	4.93×10^{-8}	8.90×10^{-6}	-0.00114	80% Corn Oil & 20% Olive Oil
0.00177	6.10×10^{-8}	1.52×10^{-5}	-0.0033	70% Corn Oil & 30% Olive Oil
0.023475	-6.46×10^{-7}	4.24×10^{-4}	-0.0617	60% Corn Oil & 40% Olive Oil
0.011061	3.80×10^{-7}	-2.26×10^{-4}	0.0346	50% Corn Oil & 50% Olive Oil
0.005155	2.72×10^{-8}	-1.32×10^{-5}	0.00261	40% Corn Oil & 60% Olive Oil
0.07365	-1.14×10^{-6}	7.16×10^{-4}	-0.111	30% Corn Oil & 70% Olive Oil
0.009953	-3.94×10^{-8}	3.58×10^{-5}	-0.00627	20% Corn Oil & 80% Olive Oil
0.036492	2.33×10^{-7}	-1.37×10^{-4}	0.0206	10% Corn Oil & 90% Olive Oil
0.02457	-7.40×10^{-8}	4.93×10^{-5}	-0.00763	0% Corn Oil & 100% Olive Oil

Table (3.6.2)
The fitting constants of the polynomial equation of the experimental coefficient of volumetric expansion versus temperature for all concentrations of olive/acetone solutions.

MRE	C_γ (K^{-3})	B_γ (K^{-2})	A_γ (K^{-1})	**Percentage of Concentration**
0.000102309	-2.97×10^{-7}	3.94×10^{-5}	0.022	5% Acetone& 95% Olive Oil
0.052155771	1.02×10^{-6}	-6.15×10^{-4}	0.1	10% Acetone& 90% Olive Oil
0.000770303	-2.00×10^{-8}	4.28×10^{-6}	0.01	15% Acetone& 85% Olive Oil
0.000166322	2.04×10^{-8}	3.95×10^{-6}	0.00595	25% Acetone& 75% Olive Oil
0.000675463	6.86×10^{-8}	2.17E-05	-0.00305	30% Acetone& 70% Olive Oil
0.00434359	-1.46×10^{-7}	1.93×10^{-6}	0.0177	35% Acetone& 65% Olive Oil
0.008747954	-2.97×10^{-7}	3.94×10^{-5}	0.022	40% Acetone& 60% Olive Oil

Prod'homme proposed an optical model that can be defined by differentiating the Lorentz Lorenz equation with respect to the temperature. From this equation we can obtain the thermal expansion of any liquid system using the calculating values of temperature gradient of refractive index (Silva *et al.*, 2007; Ando, 2006).

$$\gamma_V = \frac{-6n}{(n_D^2-1)(n_D^2+2)}\frac{dn}{dT} \text{.........,} \quad (3.6.3)$$

The above Prod'homme relation (PR) can account for both positive and negative values of dn/dT observed in different liquid systems. The thermal expansion coefficient calculated from this equation does not depend on the incident photon energy (Silva *et al.*, 2007). Gupta (Gupta *et al.*, 2012) used this equation to calculate the thermal expansion for ascorbic acid and aqueous sacharide solutions at different temperatures.

Figures (3.6.3) and (3.6.4) illustrates the thermal expansion calculated by Prod'homme optical model for all concentrations of olive/corn oil mixtures and olive/acetone solutions. The effect of temperature on the optical coefficient of thermal expansion could be accurately fitted by polynomial equation:

$$\gamma_V = A_\gamma + B_\gamma T + C_\gamma T^2 \text{..........} \ (3.6.2)$$

The fitting constants A_γ, B_γ, and C_γ are given in tables (3.6.3) and (3.6.4) for all concentrations of olive/corn oil mixtures and olive/acetone solutions.

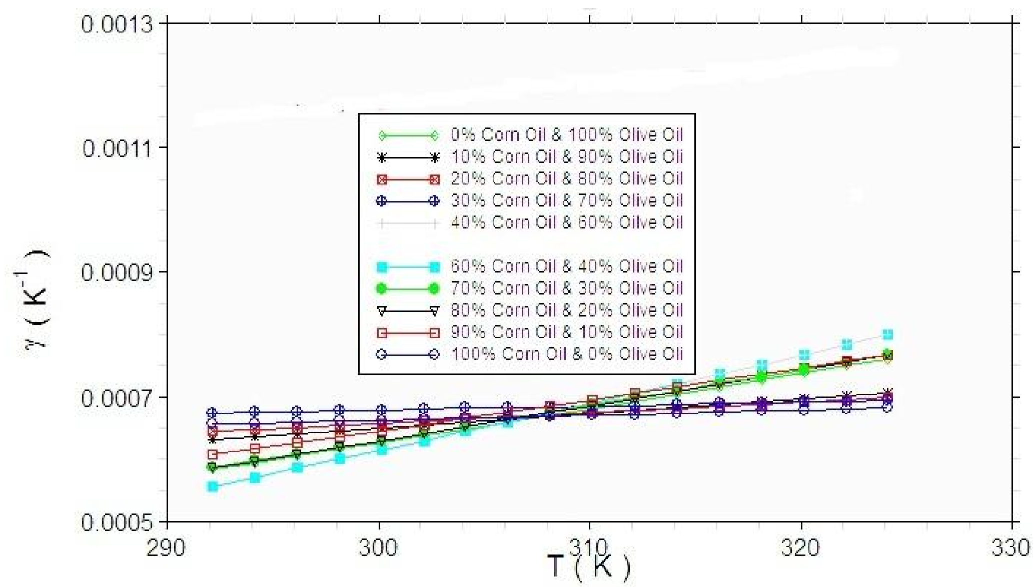


Figure (3.6.3)
The optical coefficients of thermal expansion versus temperature for all concentrations of olive/corn oil mixtures.

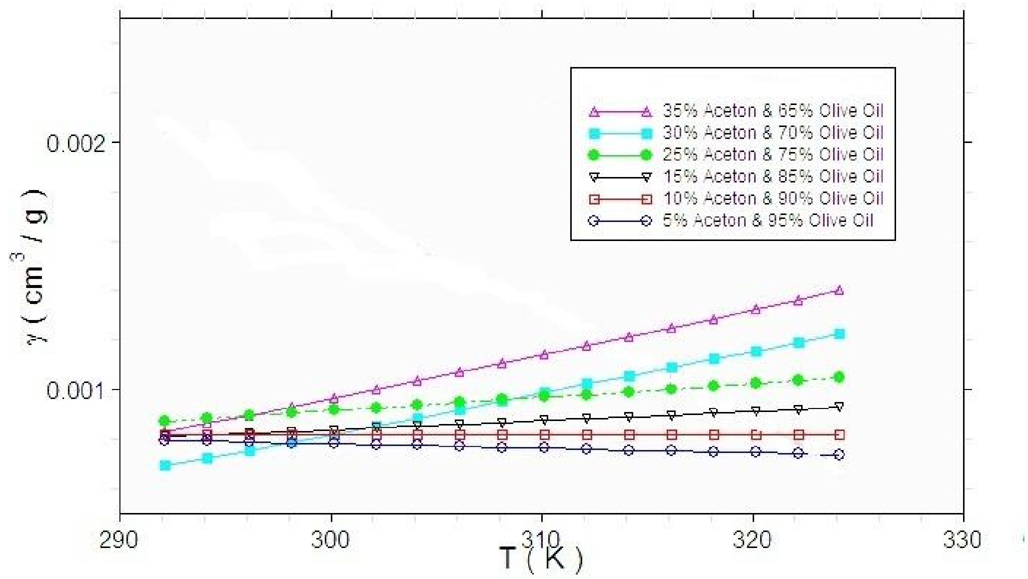


Figure (3.6.4)
The optical coefficients of thermal expansion versus temperature for all concentrations of olive/acetone solutions.

Table (3.6.3)
The fitting constants of the polynomial equation of the optical coefficient of thermal expansion versus temperature for all concentrations of olive/corn oil mixtures.

MRE	C_γ (K^{-3})	B_γ (K^{-2})	A_γ (K^{-1})	**Percentage of Concentration**
7.6×10^{-5}	7.12×10^{-10}	3.65×10^{-7}	0.000489	**100% Corn Oil & 0% Olive Oil**
0.000367	6.86×10^{-9}	8.26×10^{-7}	-0.00022	**90% Corn Oil & 10% Olive Oil**
0.001126	6.99×10^{-9}	1.35×10^{-6}	-0.00041	**80% Corn Oil & 20% Olive Oil**
0.000404	7.48×10^{-9}	1.06×10^{-6}	-0.00036	**70% Corn Oil & 30% Olive Oil**
0.005781	1.02×10^{-8}	1.32×10^{-6}	-0.0007	**60% Corn Oil & 40% Olive Oil**
0.000428	3.15×10^{-9}	6.02×10^{-7}	1.94×10^{-4}	**50% Corn Oil & 50% Olive Oil**
0.005781	3.4×10^{-9}	-1.4×10^{-7}	0.000362	**40% Corn Oil & 60% Olive Oil**
0.000525	4.99×10^{-10}	3.47×10^{-7}	0.00053	**30% Corn Oil & 70% Olive Oil**
0.00111	1.98×10^{-9}	4.83×10^{-7}	0.000335	**20% Corn Oil & 80% Olive Oil**
0.000974	2.48×10^{-9}	7.94×10^{-7}	0.000189	**10% Corn Oil & 90% Olive Oil**
0.000329	6.51×10^{-9}	1.54×10^{-6}	-0.00042	**0% Corn Oil & 100% Olive Oil**

Table (3.6.4)
The fitting constants of the polynomial equation of the optical coefficient of thermal expansion versus temperature for all concentrations of olive/acetone solutions.

MRE	C_γ (K^{-3})	B_γ (K^{-2})	A_γ (K^{-1})	**Percentage of Concentration**
0.000826411	3.63×10^{-9}	4.63×10^{-7}	2.28×10^{-4}	5% Acetone& 95% Olive Oil
0.000348334	-9.61×10^{-10}	2.82×10^{-7}	7.29×10^{-4}	10% Acetone& 90% Olive Oil
0.005298363	-8.04×10^{-9}	-9.76×10^{-8}	0.00152	15% Acetone& 85% Olive Oil
0.004578329	-3.78×10^{-9}	-1.21×10^{-7}	0.00106	25% Acetone& 75% Olive Oil
0.001588449	-1.01×10^{-8}	9.28×10^{-7}	0.00153	30% Acetone& 70% Olive Oil
0.003685326	-2.49×10^{-8}	-3.94×10^{-7}	0.00326	35% Acetone& 65% Olive Oil
0.004374253	-1.46×10^{-8}	-6.24×10^{-7}	0.00232	40% Acetone& 60% Olive Oil

3.7. Comparison Study.

In order to prove the accuracy of what has been measured or calculated published previously. Table (3.7.1) shows the density, refractive index and Lorentz Lorenz specific of refraction for pure olive and corn oils at 298.15K, which has been measured in this study and in other published researches.

Table (3.7.1)
Density, refractive index and Lorentz Lorenz specific of refraction for pure olive and corn oils at 298.15K, which has been measured in this study and in other published researches.

Physical Property	**ρ (g/mL)**	**n_D**	**R_D (mL/g)**
		This Study	
Olive Oil	0.9320	1.4695	0.299085
Corn Oil	0.9356	1.4730	0.299838
		Rudan-Tasic 1999	
Olive Oil	0.91037	1.4674	0.30502
Corn Oil	0.91655	1.4727	0.30557

Figures (3.7.1-3) show the refractive index versus percentage of the adulterated of vegetable oils, which have been measured in this study and in other published researches. (Ariponnammal, 2012) reported the refractive index versus the adulteration percentage of palm oil with coconut and sunflower oils.

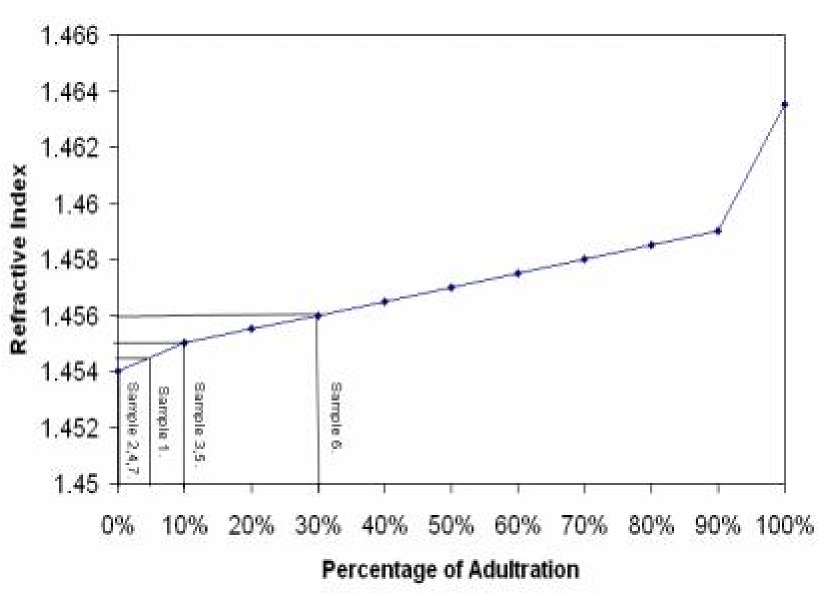


Figure (3.7.1)
The refractive index versus percentage of adulteration of palm oil with coconut oil (Ariponnammal, 2012).

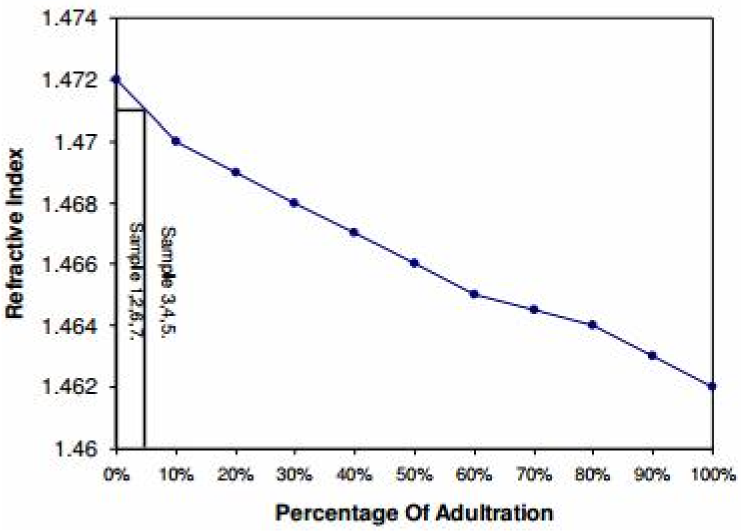


Figure (3.7.2)
The refractive index versus percentage of adulteration of palm oil with sunflower oil (Ariponnammal, 2012).

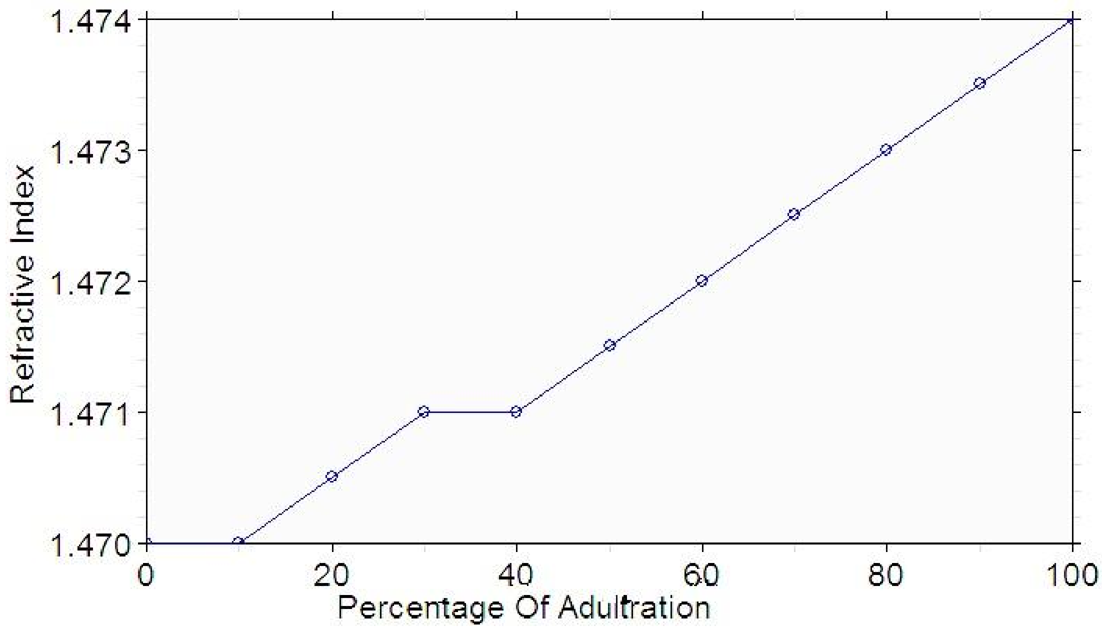


Figure (3.7.3)
The refractive index versus percentage of adulteration of olive oil with corn oil (This study).

Figures (3.7.4) and (3.7.5) show the dynamic viscosity versus temperature of olive and corn oil, which have been measured by this study and by other researches.

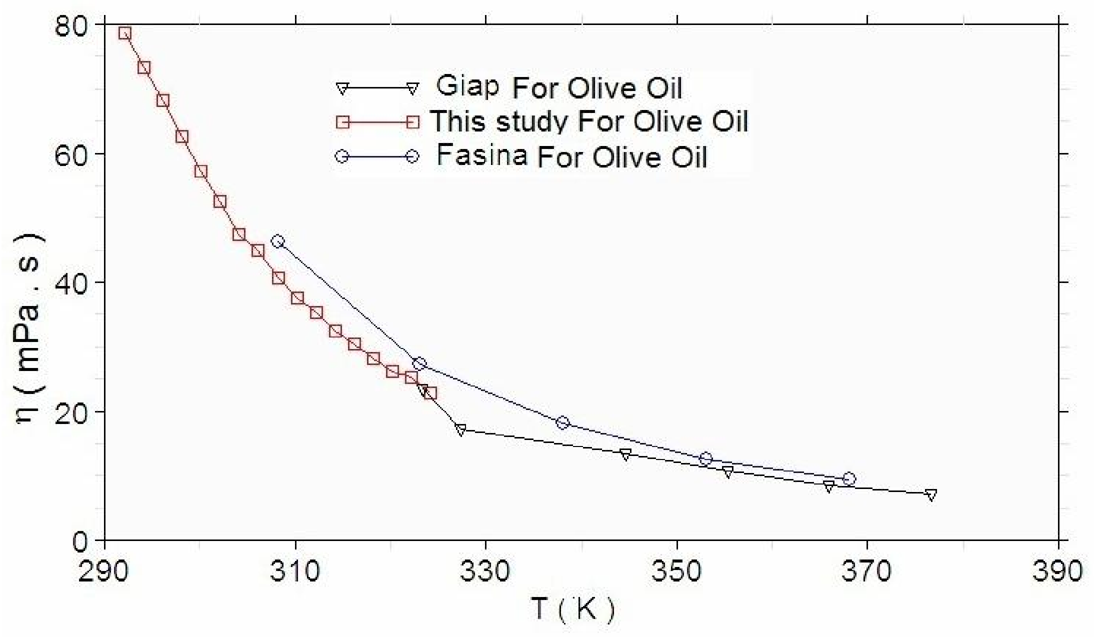


Figure (3.7.4)
The dynamic viscosity versus temperature of pure olive oil, which have been measured by us and other researches.

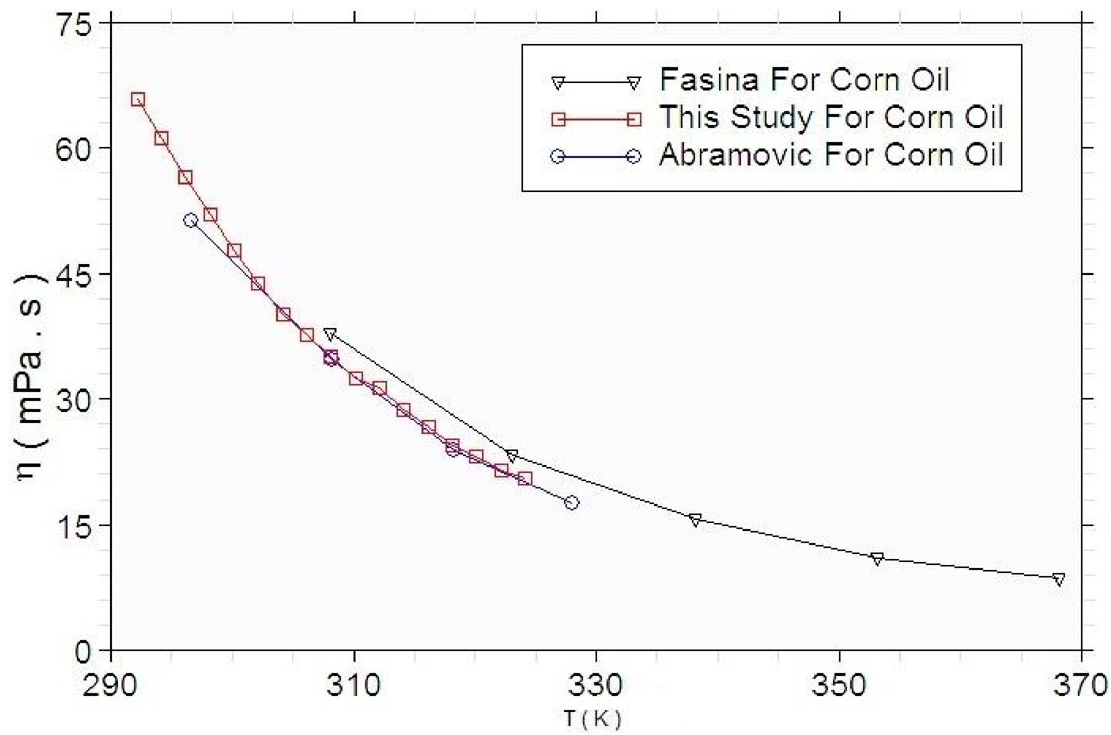


Figure (3.7.5)
The dynamic viscosity versus temperature of pure corn oil, which have been measured by us and other researches.

Table (3.7.1) and figures (3.7.4-5) show the satisfactory agreement between the measured values of physical properties in this study to the corresponding values available in other published researches. The dynamic

viscosities of olive and corn oils versus temperature are in excellent agreement with those reported by (Abramovic, 1998; Fasina, 2008) and Giap (2010).

3.8. Conclusions.

In this physical study we reported the measured and calculated of some mechanical and optical properties for different concentrations of olive/corn oil mixtures and olive/acetone solutions in the temperature range between 19 to 51^{o}C. A comparative study has been illustrated for all samples between the theoretical models, which are describe the effect of temperature and concentration on density, refractive index, dynamic viscosity and thermal expansion. The agreement between the calculated and measured values in this research with the values published in other scientific researches confirms the accuracy of used methods. From the results of this study we can mention the following conclusions:

1- The adulteration of vegetable oils can be easily obtained using the experimental measurements of refractive index.
2- This study reveals that the empirical mixing rule relation which gives the best prediction for the temperature dependence of refractive index is described by Newton equation.
3- This study verified that the specific refraction is independent on temperature for all theoretical modeling equations.
4- This study reveals that the empirical relation which gives the best prediction for the temperature dependence of dynamic viscosity is described by Vogel equation.
5- Study of thermal expansion verified the agreement between the experimental results with the calculated results obtained optically using Prod'homme equation.
6- During this study was to find a set of polynomial equations that describe the relationship between temperature and temperature gradient of measured and calculated mechanical and optical properties.

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